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LED-based Mediamesh P. 9

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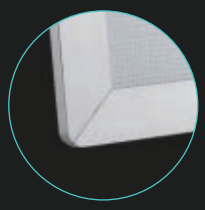

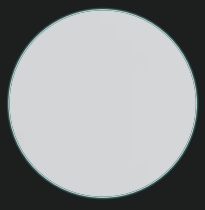

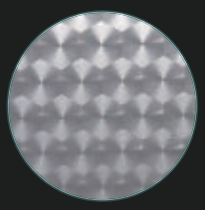

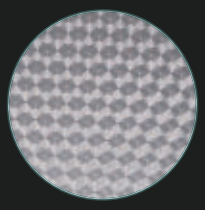

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Cover Story

Transparent façade-based screen leverages SSL technology to display student artwork in static and moving images (see p. 9; image courtesy and © GKD/Connor Elder).

features

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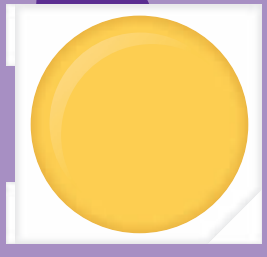
Mid Power and Low Power LEDs that meet high standards. Yours.



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California missteps with Title 20 LED lamp regulations

In January, the California Energy Commission (CEC) finalized new regulations that will impact LED-based general-service lamps including the ubiquitous A-lamps and small-diameter directional lamps (http://bit.ly/21AlHsJ). After publishing voluntary guidance encouraging the move to higher-CRI products back in 2013, the agency will now mandate such products with the policy becoming active in January 2018. It seems, however, that the CEC has delivered new rules that don't make practical sense and could result in more energy being consumed while costing California residents more in lamps and energy to light their homes.

Now the Title 20 Appliance Efficiency Regulations are hugely complex, and address far more than solid-state lighting. And even the regulations on lighting are overly complex and hard to digest. But the most controversial element of the policy is quite simple. The agency is requiring 90-CRI lamps. The document actually specifies a minimum of 82 CRI. But it also requires a minimum of 72 CRI for each of the eight pastel color samples that are averaged to determine the aggregate CRI that is sometimes referred to as Ra. The National Electrical Manufacturers Association (NEMA) said there are no 82-CRI lamps on the market that score 72 or better for the light-red-purple R8 color sample. Effectively, the regulation requires 90 CRI.

The CEC has said 90-CRI lamps provide a better user experience and are needed to ensure that residential customers don't reject LED technology the way compact fluorescent lamps (CFLs) were rejected for poor performance. But that argument doesn't really hold up to close scrutiny. Residential customers across the US are buying 80-CRI lamps in volume. NEMA has pointed out in its lobbying that any danger of LED lamps suffering a CFL-type fate has been skirted.

NEMA actively fought the CRI requirements based on its belief that consumers would end up buying more-expensive, less-efficient products. Moreover, NEMA has noted that price has been the biggest obstacle to broad adoption of LED lamps, and the recent rulemaking will simply keep prices higher than necessary.

My question for the CEC is why not let the customer decide when it comes to an issue such as color rendering? I want the freedom to buy a very-high-CRI lamp perhaps to accent a painting or photograph. But I'd want the option of buying the most efficient light possible for ambient lighting in a hallway, staircase, or garage. Even 80 CRI might be overkill in some cases.

Of course, we are talking about a forward-looking policy. The new rules won't take effect for almost two years. LED technology is quickly evolving. And the efficacy penalty associated with warm CCTs and good color rendering has been on a constant decline. Maybe 90-CRI lamps would be the standard offering by the beginning of 2018 regardless of government policy.

Still, the CEC's move to regulate CRI has been simply misguided. If technology maturity and economies of scale mean that 90 CRI is the standard product offering in 2018, then the CRI element of the rulemaking was not required. If the higher-CRI products remain more costly and less efficient, then NEMA is right and the citizens lose. The CEC has stepped into a situation that should be governed by the free market rather than government policy.

Maury Wright,
EDITOR
mauryw@pennwell.com

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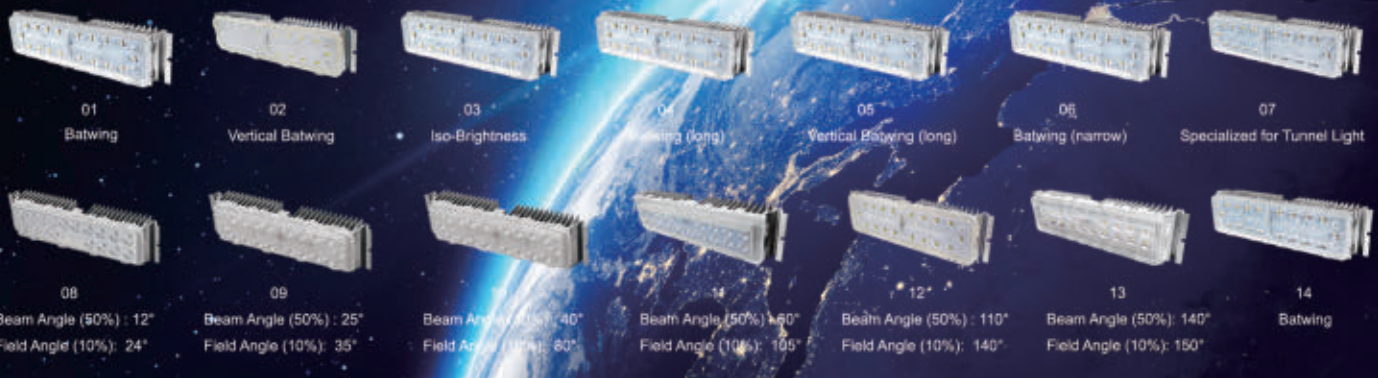

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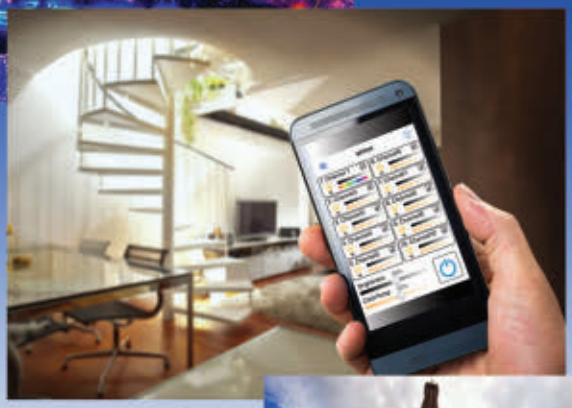

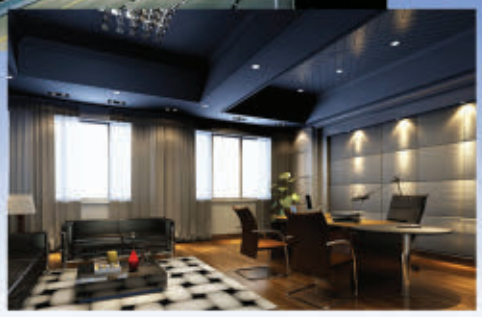

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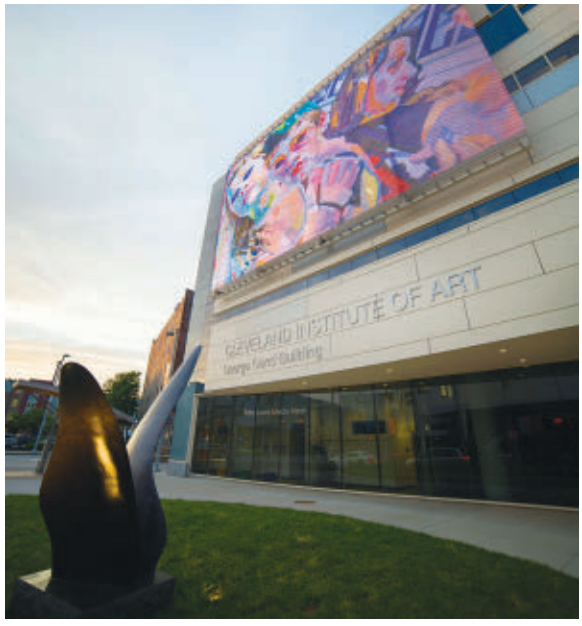
OUTDOOR DISPLAYS

GKD wraps Cleveland art institute in LED-based mesh display

The American subsidiary of GKD (Gebr. Kufferath AG), GKD Metal Fabrics, has announced an LED-based, façade-mounted video screen installation at the Cleveland Institute of Art (CIA). The solid-state lighting (SSL) project utilizes the GKD Mediamesh material that embeds LEDs in a stainless-steel metal fabric, and allows the CIA to display the work of its students in static and video form.

LED-based façade lighting spans a range of technologies from video walls and mesh-type approaches such as the one at the CIA to projected architectural lighting. For example, we recently ran a story about projected architectural lighting installed on New York's Walker Tower (http://bit.ly/1XTFvSL). And we featured a mesh-type installation from Lima, Peru on our cover back in 2014 (http://bit.ly/1KI4xuH). That project even offers control of the lighting to the public on a limited basis.



Source: © GKD/Connor Elder.

What sets the LED mesh display installations apart including the CIA work is the ability to make the SSL installation an integral part of a building's architecture while enabling dynamic images and even video content. Indeed, the GKD screen at the CIA is mostly transparent allowing natural light to enter windows behind the screen and and enabling people inside the building to see out. » page 10

CONNECTED LIGHTING

No light switches at Cisco's own Berlin smart building

One test of how much a technology company believes in its own stuff is whether it uses the gear itself. To that end, Cisco is rising to the occasion in smart lighting. As reported previously by *LEDs Magazine*, the networking giant has deployed Power over Ethernet lighting (http://bit.ly/1RRSkwT) at several of its main corporate offices, including corporate headquarters in San Jose, as well as at a regional center in Toronto. Its UK headquarters office in London will soon follow.

Source: Sabine Lobmeier via Cisco.

And to further demonstrate that it is indeed a big believer in intelligent, networked lighting, Cisco recently showed off a connected lighting project to journalists as part of a tour of its openBerlin facility. openBerlin is one of nine Cisco innovation centers around the world » page 10

RESIDENTIAL LIGHTING

Burglar deterrent LED bulbs know how and when to switch on

A Swiss-German start-up company hopes to soon give residential lighting a new role as a home security guard, as it develops LED lamps that memorize a person's room-by-room usage and subsequently switch themselves on and off in that pattern when the occupants leave home.

ComfyLight says that its system works as a burglar deterrent rather than simply as an alert once an intrusion occurs. Whereas other smart lighting systems allow users to set up a lighting pattern or to turn lights on and off remotely from afar, the ComfyLight LED lamps automatically mimic an at-home lighting scheme throughout nighttime. If, for instance, a person normally keeps living room lights on until 11 PM and then switches on bedroom lights for an hour, ComfyLights would behave in that fashion. » page 12

GKD continued from p. 9 The Mediamesh fabric includes groups of red, green, and blue LEDs that GKD calls LED profiles, which are mounted in horizontal steel channels. Smaller steel wires and vertical interconnect elements make up the supporting and mostly transparent mesh. GKD offers various versions of the product with a pixel pitch in the 40–60-mm range.

Grafton Nunes, president of the CIA, had seen mesh displays in other locations such as the large screen at the New York Port Authority Bus Terminal (http://bit.ly/1TGSSpN). In most cases, such LED displays are used for commercial purposes such as advertising. But Nunes was focused on using the technology as a communication channel between the institute's students and the public, and to provide an iconic addition to a revitalized building that is an important part of Cleveland's heritage.

The display consists of four 4×9.3m panels that comprise a display area totaling more than 150m^2. The screen includes 71,680 pixels and can display complex graphics, photos, and full-motion video clips. Still, the CIA project is unobtrusive. The institute feels that the minimalist construction blends into the architectural background while also having the ability to showcase important works.

GKD has been involved with a number of other high-profile Mediamesh projects. A few years back, we covered an installation at a Midwestern casino (http://bit.ly/21jA58D). The company also handled a project at the American Airlines Arena in Miami, FL back in 2009 (http://bit.ly/1QAc2Ha), a very early installation of large-scale LED-based displays. ◄

Cisco continued from p. 9
where Cisco and startups hash out ideas and co-develop next-generation networking technologies such as smart lighting.

As with Cisco in general these days, the facility has a distinct Internet of Things (IoT) flavor. openBerlin exudes touches you might expect for such a place: facial recognition security systems (they even work sometimes), outdoor tree houses that serve as meeting areas, a cozy café full of homey, reclaimed wooden chairs and tables that invite collaboration, and a "no-shoes" romper room up in the loft. But there's one thing you won't find.

"You don't see any light switches here," said Bernd Heinrichs, managing director of Internet of Everything (IoE) Sales for the EMEAR and for openBerlin Innovation Centre. "Everything is automated. Heating, air conditioning, the lights, et cetera...All of it's done by a huge amount of sensors."

Really? How many sensors?

"We have 5000 sensors installed now, and we probably will go to 10,000 very soon," Heinrichs said. With a capacity of about 100 people in the nearly 13,000 ft^2 building, that would work out to about 100 sensors per person — more on a typical day when the building has fewer than 100 individuals knocking about.

The sensors — largely from German supplier Bosch — are peppered around the walls and ceilings, in some cases hidden away in or near connected lighting fixtures. Some automatically adjust light settings depending on room occupancy, but they're not all for lighting per se. They detect not only room occupancy but climatic conditions like room temperature. They feed data about what they notice into the building's central IT systems, which in turn can trigger actions such as turning the heating or cooling system on, off, up, or down.

On the second floor, users can change not only on/off and brightness settings but also the color and color temperature of the ceiling panel LED luminaires via network commands, a hallmark of PoE lighting. Occupants on the ground floor, which utilizes hanging, stylish ceiling bulbs rather than panel lights, have to settle for remotely controlling on/off and brightness.

At openBerlin, Cisco has worked with two behind-the-scenes Berlin-based technology providers, Relayr and Azeti, to install software and hardware that connects lighting and other building systems to networks.

The openBerlin tour coincided with Cisco's Cisco Live! exhibition (http://bit.ly/1QgdAui), which attracted over 12,000 users, partners, app developers, and other visitors with a heavy IoT focus, and which featured a "digital ceiling" and the company emphasizing lighting and lighting partnerships with companies such as Philips, Cree, NuLEDs, Innovative Lighting, and Platformatics. ◄

MORE: http://bit.ly/1TBOylE

PACKAGED LEDS

Lumileds delivers third generation of COB LEDs

Lumileds has announced its third generation of chip-on-board (COB) packaged LEDs in the Luxeon COB Core Range Gen 3. The new LEDs hit efficacy levels of 160 lm/W in a broad family of products that span light-emitting surface (LES) diameters from 6.5 to 23 mm.

Lumileds announced the Gen 2 COB products less than one year ago in July 2015 (http://bit.ly/1WzQpx9). Those Gen 2 COB LEDs were said to have maximum efficacy in the 140–150-lm/W range. The initial Gen 2 products topped out at an LES of 15 mm, but Lumileds subsequently added a 23-mm product to the family in October 2015 (http://bit.ly/1RRTyr2).

Lumileds said it has maintained electrical, mechanical, and optical consistency in the COB line going back to the first-generation products announced in 2013. Generally, one of the benefits of COB LEDs is the simplicity of interfacing to a single LED package in product development. The Lumileds consistency further enables developers to substitute the newer, more-efficient components into lighting products while leaving holders, optics, and other elements of the product unchanged.

The latest Gen 3 COB LEDs will deliver another 10% ramp in efficacy to developers while keeping lumen output the same relative to Gen 2 products. Or developers can deliver higher output levels while maintaining efficacy. "This performance upgrade is the result of significant improvements in both die development and our industry-leading phosphor solutions that give us industry-leading performance," said Eric Senders, product line director for the Luxeon COB family.

Senders also led the team that developed the CrispWhite option in the Luxeon COB line that delivers superior rendering of colors and bright whites. That development earned

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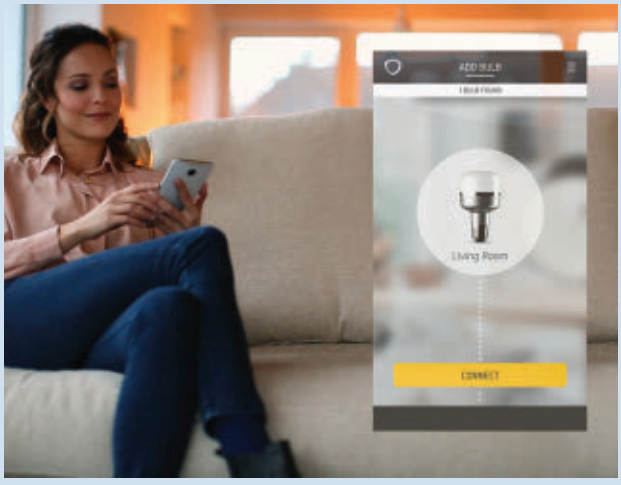
Lamp continued from p. 9

"ComfyLight is the first self-learning light bulb that's meant to prevent intrusion," co-founder Stefanie Turber says in a video on the Kickstarter crowdfunding website. "ComfyLight memorizes how you turn on and off lights when you're at home, and it simulates your behavior in a very realistic way when you're not there." The lights also turn on and off in response to motion when a user is at home.



The Zurich- and Munich-based company is pitching ease of use. The system requires a user to switch on a phone app after screwing in light bulbs to help note usage patterns. But it does not require the user to enter instructions to specifically turn on individual lamps at particular times, or to install any hubs or gateways. The app communicates with the LED lamps via Wi-Fi.

When the user leaves home, he or she switches on the app's security mode, which will turn the lights on and off in the typical at-home pattern. If an intruder enters, the lights will flash on and off to startle the burglar and alert neighbors, and the user's phone screen will turn red.

"You can start with however many ComfyLights you like and you can always add more," says co-founder Marcus Köhler, implying that the system will mimic an entire household pattern to the extent that the house is equipped with ComfyLight LED bulbs.

The company hopes to provide application programming interfaces (APIs) that will allow developers to make ComfyLight compatible with other systems, such as Philips Hue smart lamps (http://bit.ly/1Fd1uyW), and smart doorbells.

ComfyLight's crowdfunding campaign thus far echoes one run by smart lamp pioneer LIFX (http://bit.ly/1SXsasT), the Bay Area company that famously came to market with the help of $1.3 million it raised on Kickstarter in 2012 after targeting $100,000 — although ComfyLight would have a long way to go to crack $1 million.

A ComfyLight lamp includes a motion sensor, a light sensor, and a 10W LED (80W equivalent) rated at 800 lm with a color temperature of 2700K and an Ra 80 CRI. The motion sensor can differentiate between humans and pets, and works through a lampshade, the company said. With privacy in mind, ComfyLight does not build in cameras or voice recorders. The app works with both Android and iPhone handsets.

Turber and Köhler founded ComfyLight last year as a spin-off from two Swiss universities — the ETH Zurich (the Swiss Federal Institute of Technology in Zurich) and the University of St. Gallen in St. Gallen, where they conducted research at the Bosch Internet of Things and Services Lab. The lab is a collaboration between the university and the Bosch Group. ◄

MORE: http://bit.ly/1RqfxTJ

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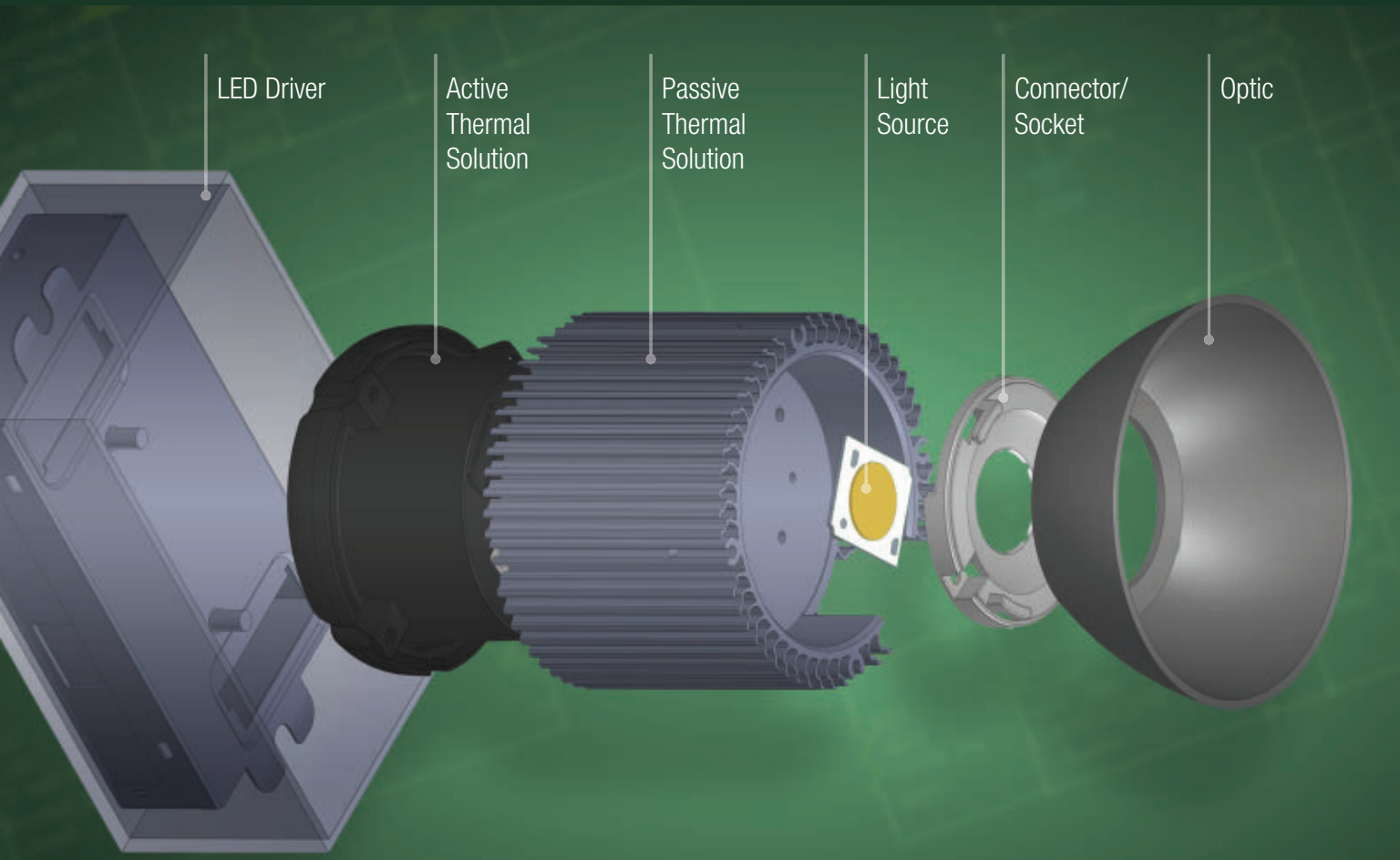

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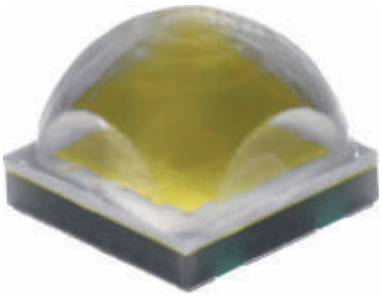
Senders and his team the 'Illumineer of the Year' award in the *LEDs Magazine* Sapphire Awards program in February of 2015 (http://bit.ly/1Dn7EcD).

The Luxeon COB Core Range is intended to cover a broad range of lighting applications. For example, the 1202 products with a 6.5-mm LES are capable of supplying spotlights with very narrow beam patterns. The largest 23-mm COB LEDs in the 1216 grouping can enable replacements for demanding applications that have been served by 100–150W high-intensity discharge (HID) lighting in indoor and outdoor applications. Lumileds offers the LEDs over the range of 2200K to 5700K CCT and in a choice of 70, 80, or 90 CRI. ◄

Cree demonstrates 134-lm/W LED with incandescent quality

Cree has announced the results of laboratory tests of a single high-power LED that delivered almost 1600 lm with light quality that matches the incandescent lamp. The company said the 134-lm/W realized efficacy is 25% better than other LEDs that can yield similar light quality. Generally, when Cree has publicized demonstrations, the company has delivered similar technology commercially about two years later.

Ironically, Cree made the announcement on the eve of the Strategies in Light (SIL) conference and one year back a prior Cree laboratory announcement came under great scrutiny at SIL. Indeed, in 2014 Cree had announced that it exceeded 300 lm/W in a lab demonstration. And in an SIL 2015 keynote presentation, Jy Bhardwaj, senior vice president of research and development at Lumileds, spent significant time explaining that a 300-lm/W LED was simply not feasible in a usable white CCT until some major roadblocks were hurdled by the industry (http://bit.ly/1F76zF5).



It's impossible to know how or if Bhardwaj's SIL speech impacted Cree's technology and marketing plans. But the company had previously announced record efficacy milestones with admittedly cooler CCTs and

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lower CRI than might be desirable for commercial interior lighting. For example, Cree executive Norbert Hiller used an SIL keynote in 2013 to announce the 276-lm/W milestone for an LED in the 4000K-CCT range (http://bit.ly/1mUmqgl).

The latest Cree efficacy milestone is different in that the lighting-quality targets are high. Cree said the demonstration was based on an LED that could deliver 90 CRI or better and also 90 or better for the R9 saturated-red color sample that is so important in applications such as retail lighting. Moreover, the CCT target is the 2700K warm hue of the legacy incandescent.

"Today, advancing LED technology goes beyond just increasing lumens per watt," said John Edmond, Cree co-founder and director of advanced optoelectronics. "Cree is also focused on improving spectral content and the efficacy of warmer color temperatures while pursuing tremendous opportunities to increase lumens per watt at real-world operating conditions. This R&D result continues Cree's high-power LED technology innovation and provides a path to better lighting experiences at the lowest overall system cost."

The Cree announcement is perhaps more important relative to some recent regulatory activity. The California Energy Commission (CEC) has adopted new rulemaking that will require 90-CRI lamps beginning in 2018 (see page 5). We can't predict at this time whether California will be an outlier in that requisite, or if other parts of the US and regions around the globe will follow the state's lead.

Cree's demonstrated ability to deliver commercially on lab products in two years would synchronize nicely with the CEC Title 20 ruling. Cree said the LED delivered 1587 lm at 350 mA of drive current and at a realistic temperature of 85°C. Cree hinted that the demonstration relied on the company's SC5 (silicon carbide 5) LED technology platform, although if experience is a guide the company will be at SC6 or SC7 two years hence (http://bit.ly/1xrxHf0). ◄

HOSPITALITY LIGHTING

Boise Wyndham hotel makes transition to LED lighting

Heliodon Lighting has announced an SSL project at the Wyndham Garden Hotel and Conference Center in Boise, ID, in which guest rooms and public areas were upgraded for energy efficiency. The 151,000-ft² interior of the hotel had consumed 286,025 kWh and after the LED retrofit that number dropped to 71,456. Moreover, Heliodon found LED products that were mostly rebate eligible, thereby helping the hotel to afford the large-scale hospitality lighting project.

Hotels have been a popular setting for LED usage since the earliest days of the SSL revolution due to the fact that the lighting in such settings is used for long hours. Indeed, the US Department of Energy (DOE) did a Gateway project all the way back in 2010 at a major San Francisco, CA hotel and documented a fast 1.1-year payback (http://bit.ly/1LHR5ZF). Still, that DOE project and oth-

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ers have sometimes struggled to find LED-based products for all of the different elements of a hotel lighting system.

Heliodon Lighting is a consultant and distributor that engaged with the Boise hotel to try and fill all of the needed interior lighting with LED sources. "Heliodon Lighting worked to find an LED solution for every fixture I had," said Nick Bhati, general manager at the Wyndham Garden Hotel and Conference Center. "They handled all the paperwork, conducted all inspections and audits, and funded the upfront cost of the project. When it was all said and done 90% of the project was rebated. I couldn't be happier with the handling of the project and outcome."

The largest replacement task involved 1319 65W A19 lamps located in the guest rooms and other areas. The hotel wanted a product that was both brighter and more efficient. Heliodon installed ESL Vision 13W LED lamps. Nick Sullivan, owner of Heliodon, said that light levels went from 2 to 5 fc in queen rooms and from 3 to 6 fc in king rooms. Sullivan did specify rather cool 4000K-CCT lamps in the guest rooms because the owner wanted the lighting to "flatter the new room décor." But Sullivan said the lighting still has a "cozy feel" in the rooms.

Wall sconces in hallways and other public areas were the second largest part of the retrofit project. There were 230 such fixtures that used 26W compact fluorescent lamps (CFLs) and the hotel did not want to replace the fixtures. Heliodon selected 9W ESL-PL Series LED lamps for the sconces. The products will work with a ballast or directly from the AC line, but Sullivan said the ballasts were removed for better efficiency and lifetime. Light levels increased from 4 to 11 fc in the hallways.

Perhaps the most interesting element of the project involved nine 400W metal halide (MH) lamps located in an internal courtyard and pool area with 40-ft ceilings. The lights were especially problematic, needing regular re-lamping in the high ceiling and not producing enough light, while producing excessive heat. For those fixtures, Heliodon specified the EDL MUR Series retrofit kits. The 120W product required removal of the MH ballast and the addition of an LED driver. But the LEDs are rated for 60,000 hours and raised light levels from 2 to 10 fc. There were also 100W CFLs in the courtyard that were replaced with 35W WSL-CL Series corn-cob-style lamps.

The other application that included a large number of replacements was recessed cans in conference rooms, foyers, the restaurant, and the bar that used 65W BR30 lamps. ESL-BR30 LED lamps at 13W provided the dimming support desired by the hotel along with the CRI desired. In the restaurant, maximum light levels went from 4 to 12 fc.

According to Sullivan, the cost of the hotel project was just over $54,000 and rebates totaled about $49,000. Monthly savings are over $1200, resulting in a simple payback period of less than five months.

The Boise product did not involve exterior LED lighting at this time. But there have been a number of hotel projects that we have cov-

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ered that were focused on exterior LED retrofits. For example, there was a very compelling project involving façade lighting at a Portland, ME hotel (http://bit.ly/1QgxO3q). ◄

CONTROLS & LIGHTING

Cree announces LED controls project, new PAR30 LED lamps and high-bay luminaires

Cree has been busy recently, having made project, partnership, and SSL product announcements. The LED-centric company has announced a new PAR30 replacement lamp that uses the TrueWhite technology platform to deliver 90 CRI, and also recently enhanced its high-bay luminaire offering. An LED controls-centric project at technology firm Avid Solutions is delivering both energy savings and better light intended to improve employee productivity. Moreover, Cree has agreed to work with IT-networking stalwart Cisco on PoE-connected lighting (see page 9).

The connected-SSL project took place at the new Winston-Salem, NC office of Avid Solutions (see photo). Cree LED lighting is installed throughout the facility and SmartCast-enabled lighting is used in many areas. Cree said the combination of LED products and controls is delivering 70% in additional energy savings relative to what LED lighting can offer.

SmartCast is Cree's control offering that enables a plug-and-play-like installation and commissioning experience (http://bit.ly/1IN0JtA). The system uses a wireless mesh network and automatically forms groups or zones of connected luminaires based on proximity and the use of a simple remote control.

The office and engineering areas of the facility are primarily lit by CR Series LED troffers and KR Series downlights, both equipped with SmartCast. The warehouse and shipping docks are lit with the CXB High Bay luminaires discussed further along in this article. The project also utilized the LS Series linear flush-mount fixtures in industrial areas. Moreover, the exterior lighting at the facility uses the Cree OSQ area luminaire.

Also in the network and controls area, Cree announced a partnership with Cisco to work on the latter's Digital Ceiling initiative. Cree is one of several LED-based lighting companies that will offer PoE-based prod-

ucts that work with Cisco network switches.

Moving to the products space, Cree continues to stand out among LED lamp vendors for a commitment to better-performing lamps prioritized over lower-cost products. The company championed the quality and reliability message in September 2015 when it launched the second-generation of the 4Flow A-lamps (http://bit.ly/1WLz4PV). The new TW Series PAR30 lamps just announced are intended to deliver better light for demanding applications such as retail or simply to make a photo or painting shine in a residential application.

In the high-bay area, meanwhile, Cree has announced an upgraded version of the CXB High Bay that was first announced in January 2014 (http://bit.ly/1QAihL7). The newest products deliver efficacy of 113 lm/W whereas the prior products topped out at 100 lm/W. Cree said the improved efficacy would further reduce operational costs for customers and make payback periods for projects that use the new fixtures drop below three years. ◄

MORE: http://bit.ly/1WLyMZk

OUTDOOR LIGHTING

Philips teams with Cisco and Dutch energy utility Alliander on smart lighting project

As LED technology launches the lighting industry on a convergence course — some might say a collision course — with the information technology and energy industries, large companies from those sectors including Philips, Cisco, and Dutch utility Alliander have joined forces on an outdoor smart lighting project in Amsterdam, with similar projects likely to follow.

The threesome teamed with a private-public group called Amsterdam Smart City, Dutch telecom giant KPN, and others to install a connected lighting scheme and public Wi-Fi at Hoekenrodeplein, a large modern square with shops, hotels, and music that's near Amsterdam Arena — the city's main soccer (football) stadium and mega concert venue.

They officially switched on Hoekenrodeplein in early February, ahead of a Cisco customer and partner gathering in Berlin where Cisco and Philips revealed more details of their connected lighting plans such as the partnership they announced in December (http://bit.ly/1IknZ6w).

Cisco, Philips, utility Alliander, and Eindhoven University of Technology's Intelligent Lighting Institute began co-developing urban smart lighting schemes in October 2012 in an initiative called Smart Lights in Metropolitan Areas, targeted at the Dutch cities of Amsterdam, Rotterdam, and Eindhoven.

The Hoekenrodeplein installation in Amsterdam's Zuidoost (southeast) district is a product of that collaboration, and represents a sprucing up of the zone's entertainment area and an effort "to meet the request of the City District to turn the Hoekenrodeplein into a safe and pleasant place to live and use," Amsterdam Smart City said on its

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website (http://bit.ly/1Un5dPf).

"The square is completely rebuilt," it noted. "Different applications have been realized...like adaptive lighting, cameras and a public Wi-Fi network. The streetlights can be adapted from a distance or can be automatically adapted through sensors. This can be adjusted to different circumstances, for example to a different atmosphere, to a type of event or to the weather."

Amsterdam Smart City did not say exactly what role Alliander is playing but noted, "In the future the system will dim the lights and more energy will be saved. This energy can be used for the supply of a Wi-Fi network or to measure the air quality. The next step is to further expand these smart street lights to the Arena Boulevard and in the whole area surrounding it. Also different opportunities to communicate for visitors, the catering industry, and retailers will be added in the future. This initiative serves as a base for other projects in Amsterdam on a bigger scale."

Intelligent lighting taps wired and wireless information technology networks to allow users to remotely and dynamically change lighting brightness, colors, and the like. It also embeds sensors into luminaires and lighting fixtures/accessories such as lamp posts to note everything from crowds, traffic, parking conditions, air quality, and much more, and to feed that information to systems and users who could benefit from it.

According to Innovation Arena, a group that promotes progressive designs in the Arena area, the Hoekenrodeplein smart lighting allows the district to use lighting to deter soccer hooligans. "Angry football fans making a ruckus on the square will be faced with ultrabright lights, making them more visible to the police and surrounding cameras," it said on its website (http://bit.ly/1QgG7jf).

The Dutch project provides an early example of how the lighting industry and the IT and energy worlds are trying to cooperate on intelligent lighting. What's not clear is how the different parties will work out business terms and go to market arrangements between them (http://bit.ly/1RRSkwT). Some industry observers believe that ultimately IT circles, rather than traditional lighting companies, will drive the modern lighting industry. ◄

LED BUSINESS

Osram CEO: We have received offers for lamps division

Osram CEO Olaf Berlien has told analysts that the company has received a round of informal offers for its lamps division, and that it is "still aiming for legal separation" of the group by July 1. But the timing of the "legal separation" does not necessarily equate to that of the sale of the division, which could take longer, Osram clarified.

"We have received several non-binding offers and are in discussions with potential buyers," Berlien told analysts during a call to discuss results for the 2016 first quarter, ended Dec. 31, 2015.

In response to a question from Bank of America Merrill Lynch analyst Kai Mueller, Berlien did not say when he thought Osram would complete the sale of the division.

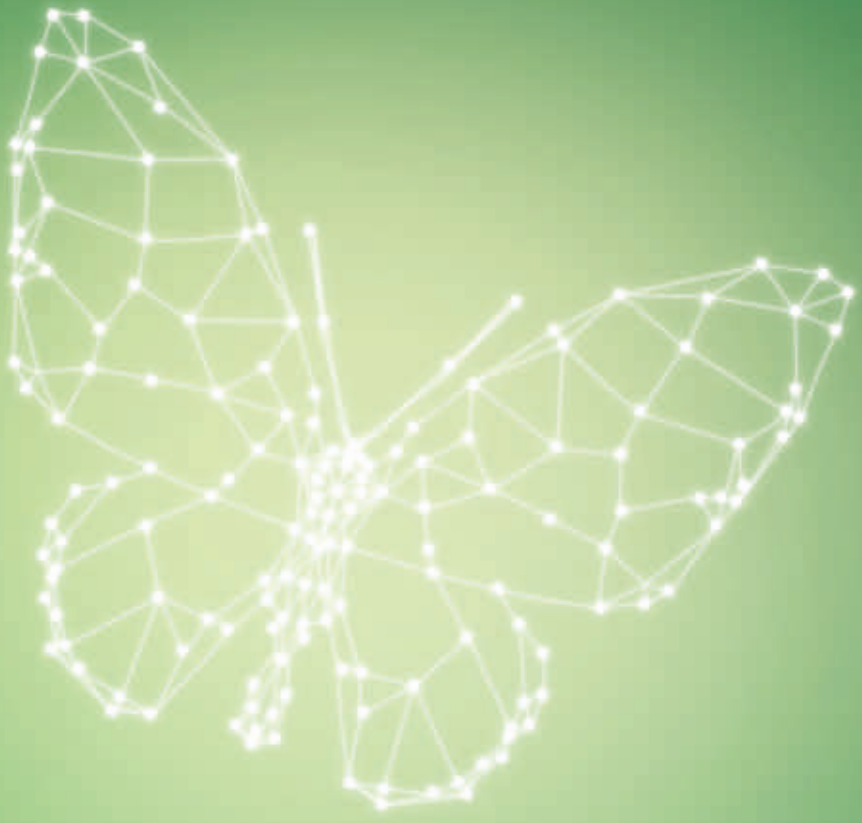
"We are in the very early stage — we just received the first, the non-binding offers," he said, adding that due diligence will follow and that "I would expect something late spring where we have a better visibility of where we are." He did not identify the bidders. The company received an informal offer from China's Shanghai Feilo Acoustic last July.

Osram says it is still on track to complete an "organizational separation" of lamps by April 1, and a "legal separation" by July 1.

In the April separation, lamps will have its own dedicated personnel, an Osram spokesperson told *LEDs Magazine*. By July the group would become a separate legal entity by the name of LEDVANCE, and Osram will have completed the "carve-out" of the division.

Previously, Osram outlined plans to strengthen its services-oriented Lighting Solutions and Systems division (LSS), with Berlien saying that it would consider acquiring companies in that area. ◄

MORE: http://bit.ly/1KL6g9e



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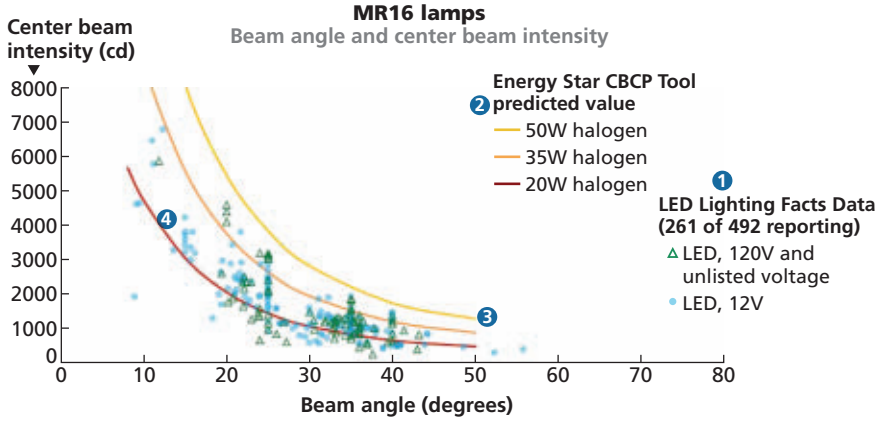
DOE updates LED MR16 lamp report, adds to white-tunable data

The US Department of Energy (DOE) has published a Caliper Snapshot report that finds only meager progress in LED-based MR16 lamps over the course of two years since the agency last published a similar report. New products have improved color rendering but generally the solid-state lighting (SSL) alternatives cannot match the performance of 50W halogen lamps. The DOE has also released an addendum to Caliper "Report 23: Photometric testing of white-tunable LED luminaires" that seeks to answer the question of how many correlated color temperature (CCT) test points are required for accurate operational characterization of such products.

MR16 snapshot

The DOE had previously released an MR16-centric Caliper Snapshot report in January of 2014 (http://bit.ly/1p7PQuF). That report two years back lamented the fact that lamp manufacturers weren't able to match the performance of 50W halogen products and little has



changed. The new report said there are good LED alternatives to 20W and 35W halogens but not for the brighter 50W MR16 lamps. Moreover, the new report said it is the 50W products that are most commonly used.

Mean efficacy has increased from 54 lm/W to 61 lm/W over the course of two years, but that performance ramp is shallower than in larger-form-factor directional and omnidirectional lamps. And the DOE said no available products can meet Energy Star requirements for center beam candle power (CBCP) for any given beam angle, although the CCT and color rendering index (CRI) specs do comply with Energy Star requirements.

There are a variety of potential reasons for the technology stagnation in MR16 SSL products. As we have mentioned in the past, the small form factor makes integrating the driver, LED sources, thermal elements, and optics extremely challenging. » page 28

DOE publishes report on the accuracy of flicker meters in characterizing LED-based lighting

Flicker continues to be an area of great concern in LED-based lighting. While the industry moves to develop test methodologies for flicker, the DOE has performed testing on three test and measurement (T&M) products that are claimed to be able to measure characteristics including percent flicker, flicker index, and fundamental frequency — parameters that have been defined in the *Illuminating Engineering Society (IES) Handbook*. A new report finds that the commercial flicker meters generally deliver accurate results, although there are notable exceptions based on situations such as sources with high fundamental frequencies or based on the configuration of the meters being tested.

We covered the complexity of the flicker issues in a recent feature article (http://bit.ly/1MPxg1A). Flicker can be a problem with any lighting, and has been especially problematic with some LED-based products especially when dimming is involved. As the DOE noted, both the IES Testing Procedures Committee and the CIE (International Commission on Illumination) Technical Committee 1-83: Visual Aspects of Time Modulated Lighting Systems are pursuing potential standardized test methodologies to accurately characterize flicker.

Still, at least three T&M companies have added the capability of delivering the existing flicker metrics defined by the IES. The products include: the BTS256-EF Lightmeter from Gigahertz-Optik, the LFA-2000 Light Flicker Analyzer from Everfine, and the SC-ASTR-10 Illuminance Photometer from Admesy Asteria. The DOE sought to compare the operation of the products to a reference test system developed at the DOE's Pacific Northwest National Laboratory (PNNL) with that system comprising multiple instruments and a photosensor.

Flicker from page 25

The DOE tested 14 SSL products that it had on hand with each of the three commercial test products and with its reference system.

The results of the DOE testing are tough to simply quantify. Such measurements are complex and involve detailed settings in the instruments. Moreover, once a light sample is captured, the equipment performs a complex set of mathematical operations before delivering results in spreadsheet form.

The DOE took two sets of measurements with each of the test equipment sets and each of the sample light sources. Short-duration tests used a 100-ms (millisecond) measurement time and long-duration tests used a 1s measurement time.

The biggest deviation came in fundamental frequency measurements. Specifically, the DOE noted that huge differences in the results can happen with sources that have high-frequency content located far above the 120-Hz fundamental frequency that is predominant in many products that rectify the AC line. LED-based products that use pulsewidth modulation to control light-intensity levels could fall into this group.

The DOE reported that 75% of the percent flicker measurements made by the commercial products were within 3% of the reference value. And 75% of the flicker index measurements were within 0.066. The nearby table summarizes the results.

You can read the full results of the report on the DOE website (http://1.usa.gov/20WYprn).

MORE: http://bit.ly/1RtPpaO

DOE flicker parameter test results on commercial flicker meters.

	State	**Percent flicker:** Max. difference (70th, 90th, 95th percentile)			**Flicker index:** Max. difference (70th, 90th, 95th percentile)			**Fundamental frequency:** Min. % match (short, long duration)	
Measurement and calculations	Dim	3	5	6	0.066	0.135	0.192	58	8
	Full	2	5	6	0.049	0.029	0.044	64	57
Calculations (only)	Dim	1	2	2	0.007	0.074	0.222	58	25
	Full	1	2	3	0.004	0.004	0.021	64	64
Measurements (only)	Dim	3	4	5	0.065	0.118	0.154	83	67
	Full	2	6	6	0.006	0.010	0.019	93	86

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Nichia 757D

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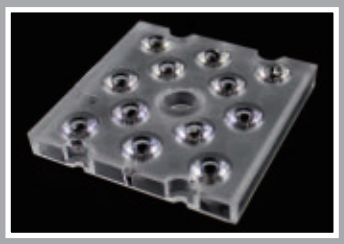
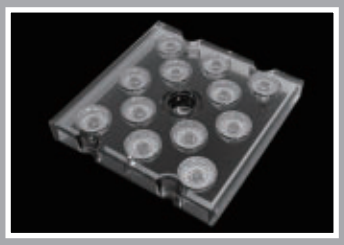


LL12ZZ-CRC25L19
DxWxH(mm) 50x50x6.3
FWHM 25°
Lumileds Luxeon 3030
Nichia 757D



LL12ZZ-CRC55L19
DxWxH(mm) 50x50x6.3
FWHM 55°
Lumileds Luxeon 3030
Nichia 757D

Street Lighting

LL12ZZ-CRC45155L19 (type II-M)
DxWxH(mm) 50x50x5.3
FWHM 45x155°
Lumileds Luxeon 3030
Nichia 757D

LL12ZZ-CRC45145L19 (type II-S)
DxWxH(mm) 50x50x5.3
FWHM 45x145°
Lumileds Luxeon 3030
Nichia 757D

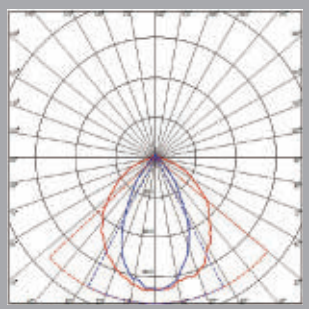
LL12ZZ-CRC60155L19 (type III-M)
DxWxH(mm) 50x50x5.3
FWHM 60x155°
Lumileds Luxeon 3030
Nichia 757D

LL12ZZ-CRC60145L19 (type III-S)
DxWxH(mm) 50x50x5.3
FWHM 60x145°
Lumileds Luxeon 3030
Nichia 757D

Indoor Lighting (Developing)

Linear Lens

DxWxH(mm) 286x32.4x6.7
FWHM 60° 90°
Seoul 5630 LG 5630
Nichia 757D



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Lens Application

MR16 from page 25

But the DOE also noted market forces at play. The new report said there is far more incentive for companies to focus on other LED-lamp sectors such as LED-based T8 tubes where the SSL alternative must compete with an energy-efficient fluorescent incumbent. In the MR16 sector, the LED lamps are already delivering considerable energy savings even if CBCP trails the legacy halogen lamps.

The DOE also noted that MR16 lamps are often used in applications such as retail where excellent color rendering is critical. Manufacturers supplying products for such applications may have necessarily focused on optimum CRI rather than on maximum energy savings in the LED alternatives. But the DOE also said that by pushing harder on efficacy, manufacturers would find the small-form-factor and thermal challenges easier to overcome in targeting 50W halogen performance. The entire report is on the DOE SSL website (http://1.usa.gov/1QA635l).

Tunable white

The addendum to Report 23 on tunable-white lighting technology follows the original report published in September 2015 (http://bit.ly/1mZA4DT). That original report had focused on the need for luminaire makers to take detailed electrical and photometric measurements at 11 different CCT set points over the range of CCTs that a luminaire could produce.

While the use of 11 points would provide a comprehensive view into the performance of a tunable lighting product, such a requirement would place a significant burden on luminaire manufacturers that have to perform these tests. The DOE's latest work compares the results from the 11-point tests with those that relied on only 3, 5, or 6 CCT set points. The agency sought to discover whether such simpler testing would provide lighting specifiers/designers with accurate operational information on a tunable luminaire.

The issue at hand largely comes down to how tunable luminaires are designed and therefore how light output and power consumption vary over the tunable range. With only 3 set points defined, the DOE found that lumen output errors could be as large as 10% relative to the 11-point characterization and the error in specified power draw might be as high as 6%. Those error ranges each drop to 3% when 6 points are tested.

The DOE warned that its tests were performed on a small sample of five products and that other designs could exhibit substantially different characteristics. That said, the 6-point characterization would be sufficiently accurate for many SSL projects. Still, the tests only applied to tunable white lighting products that have generally linear tunable performance and not to dim-to-warm or full-color-tunable products. The complete tunable lighting report with the addendum is available for review and download on the DOE website (http://1.usa.gov/1OFl8oK). ◄

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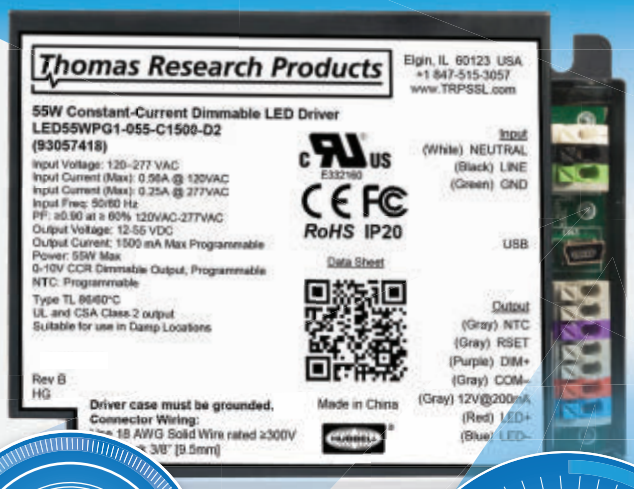

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LED-lit Texas plaza demonstrates uniform lighting, no spill

MAURY WRIGHT details a parking-area SSL project in Allen, TX that showcases the beam control enabled by LED sources in terms of uniformity and minimal light spill.

One of the many advantages of LED-based lighting is precise beam control, and that attribute is very important in area-lighting applications such as a recent project completed by US Energy Management in Allen, TX. The Twin Creeks Village shopping plaza underwent a solid-state lighting (SSL) retrofit of its parking lot that has resulted in significant energy savings and — equally important — is delivering much-better-quality lighting. The prior high-pressure sodium (HPS) lighting was replaced by Edge High Output (HO) LED luminaires from Cree.

Plano, TX-based US Energy Management and Cree worked in a close partnership on the Twin Creeks project. US Energy Management is essentially an energy services company (ESCO) focused solely on energy-efficient lighting. Company president Brad Hitchcock said the company offers a turnkey service that includes an audit, lighting design, and installation of a project. Cree, meanwhile, has an application engineering team that is available to assist in such projects.

The property owners at Twin Creeks had asked US Energy to propose a one-for-one retrofit of the existing HPS lighting. That prior lighting design had two 1000W fixtures on each pole at a mounting height of 40 ft. The HPS lighting had delivered an average of 3.9 fc at the parking lot surface. But the owners weren't happy with the lack of uniformity that is apparent in Fig. 1 — a depiction of the prior HPS installation. (Note that if you are reading this article online or in our digital edition, there is also a video with before and after footage captured by a drone: http://bit.ly/1XN33rZ.) The HPS lighting yielded bright spots under poles and much lower light levels between poles. Fig. 2 depicts the much more uniform LED lighting.

FIG. 1. The high-pressure sodium (HPS) lighting at the Twin Creeks Village shopping plaza in Allen, TX exhibited hot and dark spots and poor color rendering.

Photometric planning

Cree's application team worked with US Energy to develop a photometric layout. The Cree team projected that an installation of one Edge HO LED luminaire per pole could deliver the desired 4 fc on average and the desired uniformity with a sharp cutoff at the property line. But the property owners believed that a dual-luminaire installation on each pole would offer better symmetry and uniformity.

The Edge HO (Fig. 3) product line was announced as an addition to the Edge series back in 2012 (http://bit.ly/1oXGk0z). The HO product was designed specifically as a replacement for HID fixtures in areas such as high-security lots and automobile dealerships (Fig. 4) that need very high output levels. Cree offers the product in 120- and 240-LED versions, and in each case with the option of 700-mA (standard) or 1A (high-power) drive current. The result is a range of just over 20,000 lm to almost 50,000 lm in output. Cree offers the products at CCTs of 4000K, 5000K, and 5700K.

Ultimately, the Cree and US Energy team settled on the installation of two 120-LED luminaires per pole at a 5000K CCT. The 421W luminaires deliver greater than 50% baseline savings relative to the prior HPS lighting. And as we will discuss shortly, late-night dimming functionality is compounding the savings.

Cutoff and reflectance

About the results, Hitchcock said, "Property ownership was amazed at what was accomplished." The LED lighting is delivering an average of 4.2 fc and, as the aforementioned video demonstrates, excellent uniformity all of the way to the perimeter of the property. What is also evident in the video is the sharp cutoff at the edges of the property with little light spill outside the boundaries, and also little to no detectable uplight.

Allen, TX is one of many communities that are moving to adopt Dark Sky ordinances. And many such ordinances are based on the Model Lighting Ordinance (MLO), a

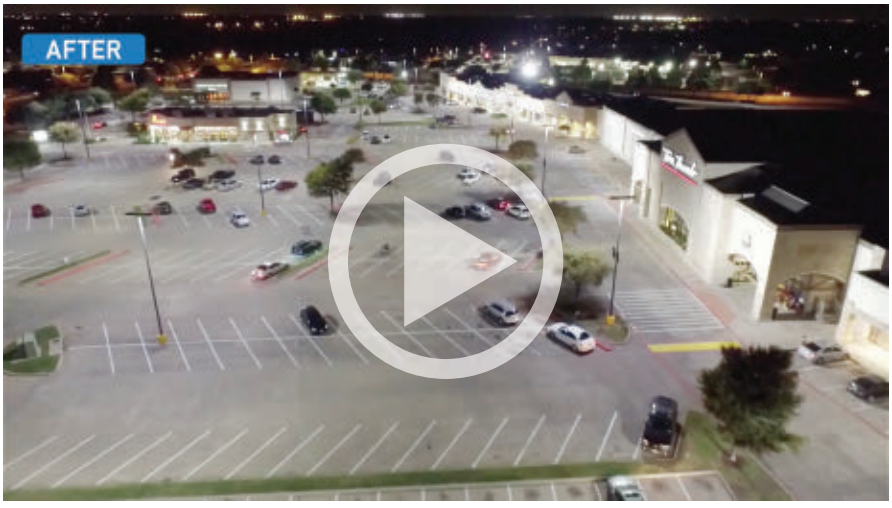

FIG. 2. Cree Edge HO LED luminaires were used to improve the uniformity of lighting in the lot to the property perimeter while minimizing light spill. Click on the image to view the embedded video or type the following URL to view the "before and after" video in your browser: http://bit.ly/1XN33rZ.

specification that was jointly developed by the Illuminating Engineering Society (IES) and the International Dark-Sky Association (http://bit.ly/1NY9W5b). Specifically, the MLO defines different classes of lighting zones and BUG (backlight, uplight, and glare) maximums for each zone type.

Cree publishes BUG data for the Edge HO product family. Moreover, the company's applications team verified compliance with all IES guidelines on the Twin Creeks project including reflectance of light from the paved parking lot.

CCT choices

We also asked US Energy about the choice of 5000K-CCT lighting and the ongoing push by some communities to move to warmer CCTs in outdoor lighting. As we covered in a recent blog post, some communities want to restrict outdoor lighting, especially street lighting, to 3000K or lower CCTs (http://bit.ly/1TvnFnX).

We will have more to offer on the CCT discussion in upcoming blog posts and articles. But the Cree and US Energy team said that 5000K was the best choice for the Twin Creeks project. Hitchcock said, "In our experience, 5000K has become the standard for commercial outdoor lighting."

Hitchcock said the LED installation appears 50% brighter than the prior warmer-CCT lighting despite the fact that the average measured light levels or fc readings are virtually identical. Moreover, the qualitative assessment of the new lighting from Twin Creeks merchants and customers has been almost universally positive. It seems in a commercial setting that perhaps people are more worried about safety and security and welcome the cooler light and what many believe to be better visibility. Those surveyed on the Twin Creeks project felt the lighting provided a safer environment. But some people clearly don't want 5000K lights on their streets.

Of course, the CRI comes into play as well. HPS lighting has a notoriously poor CRI and that makes it much tougher to discern details such as faces or even just to detect objects. We covered object detection relative to a Seattle street trial that demonstrated the advantage of LED-based lighting (http://bit.ly/1lCNmyd). The 5000K-CCT version of the Edge HO series delivers an exceptionally high CRI (for outdoor lighting) of 90 and is based on Cree TrueWhite technology.

In fact, that high-CRI rating is worth a bit deeper discussion. Typically, LED-based outdoor area lighting has a CRI in the range of 70, and that level is more than sufficient for most outdoor applications. The 5000K product from Cree, however, was optimized for auto-sales-lot lighting and that is one application where CRI really matters. The company could build 70- and 90-CRI versions of the product, and in fact the 4000K- and 5700K-CCT products have a 70 CRI. But customers that install the 5000K-CCT products get what is truly outstanding color rendering.

Dimming and sensors

Of course, one way to alleviate concerns over bright lights is to dim them. In fact, many outdoor lighting installations are overlit, especially when transitions to cooler-CCT SSL products take place. The regulatory community is playing catchup as the research community attempts to validate theories about better vision under cooler, broader-spectral-power-distribution (SPD), and/or higher-CRI lights. LED lights installed to recommendations developed for HPS sources may indeed be too bright.

In the Twin Creeks case, the property owners like the result of the project in all aspects including the light levels that give patrons a sense of security. At the pavement level, visibility even allowed one of the merchants to host late-night roller hockey games in the parking lot, according to Hitchcock.

Still, the bright light is not generally required late at night when the stores are closed. US Energy contemplated a network-based control system for the plaza, but ultimately determined that a simpler autonomous control scenario was more suitable for the application. Occupancy-sen-

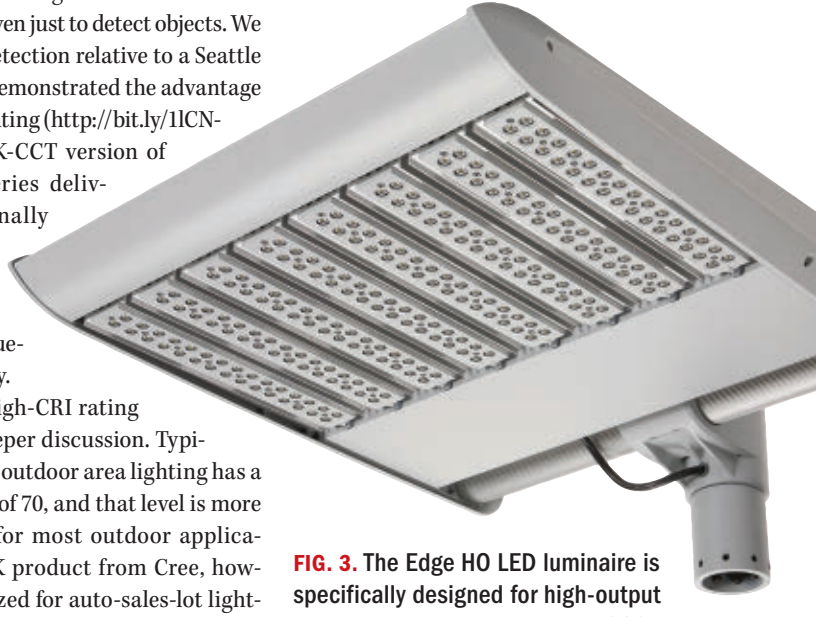

FIG. 3. The Edge HO LED luminaire is specifically designed for high-output lighting applications in which 1000W HID fixtures have been commonly used.

FIG. 4. Automotive sales lots are one application in which the Edge HO LED luminaire shines.

sor-based controls can drop the light level, and energy usage, by 50% when the area around a pole is vacant.

Occupancy- or vacancy-based controls have been somewhat problematic in outdoor settings in the past. Mainly the sensors have registered false positives based on wind-blown trees, debris, or other objects. And the sensors have been said to be especially problematic at mounting heights above 20–30 ft.

Clearly, however, the sensors are improving. Hitchcock said US Energy has used sensors at 40-ft mounting heights with success on several projects. And the Twin Creeks property owners were sufficiently pleased with the vacancy sensors that they have bought the same capability in additional outdoor projects at other plazas. In the Twin Creeks case, Hitchcock said the poles will detect autos moving within 20–30-ft of a pole, and instantly bring the lights back to full brightness.

Networks or sensors?

Still, there are other projects we have covered that suggest alternative reasons that might justify a network-based installation. Princeton University, for instance, determined that it would be best to light several poles adjacent to the one pole that detected occupancy (http://bit.ly/1Q5IFNz). Of course, that Princeton project involved college residential parking where a single student and auto might have triggered the sensor late at night. The shopping plaza will generally be fully lit during business hours and fully dimmed except for the occasional worker movement during off-business hours.

Ultimately, Twin Creeks is saving an average of 455,000 kWh based on the SSL installation. Tenants and customers are happy with the light levels and dimming. Indeed, Hitchcock again mentioned the late-night roller-hockey game. He said the poles in the immediate vicinity of the hockey rink were at full brightness while the rest of the parking area was dimmed to 50%.

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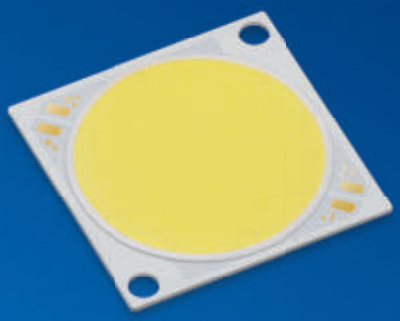

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Bluetooth Mesh — What's that noise about?

Coming Bluetooth extensions will make the wireless technology a better fit for smart lighting, explains **MAREK WIERZBICKI**, while mesh extensions will retain the low power, ease of use, and reliability of the proven radio technology.

Smart lighting might be the biggest revolution the lighting industry has seen in decades, but the multitude of available wireless communication technologies can cause a real headache for manufacturers willing to delve into this new, exciting market. Bluetooth is the latest talk of the town with its mesh networking support to be adopted later this year. We at Silvair have been deeply involved in the Bluetooth Smart Mesh Working Group's efforts aimed at standardizing a Bluetooth-based mesh architecture, and this examination of the basic concepts behind one approach to a Bluetooth Mesh implementation will give you an idea as to what Bluetooth Smart mesh networking is all about.

Lighting standards we've all known for years are now being challenged by the next generation of lighting systems that promise to deliver so much more than just a well-lit space. The transition toward digital lighting is happening right in front of our eyes, and while a couple of months ago many had doubts as to whether smart lighting could be a real deal, it now seems that there is no turning back. Over the last 12 months, we've seen multiple heavyweight lighting manufacturers spinning off big chunks of their traditional businesses to put more focus on connected technologies (See *LEDs Magazine* coverage of Osram — http://bit.ly/1KL6g9e). Smart lighting promises new business models with a steady stream of revenue from value-added features and services, which is exactly what lighting companies need to overcome the challenges resulting from the impressive longevity of LEDs and razor-thin margins in the LED market.

MAREK WIERZBICKI *is the chief marketing officer at Silvair (silvair.com).*

FIG. 1. There were a number of Bluetooth-based, mesh-enabled lighting products at the Consumer Electronics Show (CES) in 2016 including a lamp from Girard Sudron and a switch from NodOn.

Moving to networks

It is therefore not surprising that virtually every week we are hearing news about lighting manufacturers entering into agreements with companies that can relatively swiftly implement smart technologies into their products, or even straightforwardly acquiring providers of wireless connectivity, cloud services, or advanced data analytics. Things have gone so far that we've already seen Goldman Sachs downgrading its rating on one of the leading lighting manufacturers, citing concerns over the company's deteriorating earnings and emphasizing its low exposure to connected technologies. The trend is clear: Lighting systems are becoming digital, and a wide variety of smart lighting products (Fig. 1) presented at CES (Consumer Electronics Show) 2016 only confirms this (http://bit.ly/20t1qRN).

That said, there is still no consensus regarding the wireless communication protocol that could be the go-to technology for lighting applications, let alone the entire Internet of Things (IoT). Countless times has it been said that the lack of interoperability is a major obstacle to mass adoption of connected solutions, but instead of some sort of standardization, we're only seeing things getting more and more fragmented. New technologies keep emerging, each claiming to have exactly what it takes to enable seamless, robust, and secure connectivity in the Internet of Things (IoT).

In the meantime, the more mature communication standards keep evolving to address the dynamically changing customer needs, as many of them were introduced to the market when expectations and hype surrounding the IoT and connected spaces were nowhere near as big as they are today. What's more, certain product categories did not even exist back then, with smart lighting being a perfect example of a segment that has come a long way from nonexistence to being one of the hottest smart building automation segments over just a couple of years.

One of those mature standards is Bluetooth, a wireless communication protocol that seems to have been around forever and thus enjoys unmatched brand recognition. However, for certain very specific reasons, it is currently not being considered a viable option for advanced building automation

solutions. The Bluetooth Special Interest Group (SIG), a 28,000-member strong body that oversees the development of Bluetooth standards, claims this is about to change once the mesh networking support is introduced into the protocol's core specification. We are only a couple of months away from this release, so let's see what's coming.

Bluetooth Classic versus Bluetooth Smart

All that noise surrounding Bluetooth might be somewhat confusing for those not too familiar with the recent developments in the wireless communication landscape. After all, the protocol was first developed before the term "Internet of Things" was even coined. But what many are still not aware of is that the Bluetooth of today is something completely different than Bluetooth of the past.

The original Bluetooth, known as Bluetooth Classic, was designed as a short-range, cable-replacement technology for point-to-point communications. Initially, the main goal was to synchronize data between mobile phones, but the standard quickly became the default technology for wireless data exchange between personal computing equipment (mobile phones, PCs, PDAs) and peripherals (headsets, cordless keyboards and mice, printers, and such). Devices could form a tiny personal area network (PAN) called a piconet, whereby a single central device would coordinate the activity of up to seven active peripherals.

Fast-forward to 2010, the Bluetooth Core Specification version 4.0 is released, introducing Bluetooth Low Energy (BLE), more commonly known as Bluetooth Smart. This is where the story of Bluetooth in the IoT really begins. Bluetooth Smart was designed specifically to address the needs of a new generation of smart devices, many of which are battery-powered and therefore require fast connection times and efficient power management to reduce unnecessary energy consumption.

The new specification extended Bluetooth's usefulness to a whole new range of products, ultimately making it a default technology for all kinds of wearable devices. But despite some really outstanding features of the Bluetooth Smart radio, the protocol didn't make any significant impact in the building automation segment. Smart homes were dominated by other low-power technologies, mainly ZigBee and Z-Wave, and wireless communication never really took off in commercial spaces. Due to certain important drawbacks of the available low-power communication standards, building managers preferred to stick to wired solutions, considering them way more reliable.

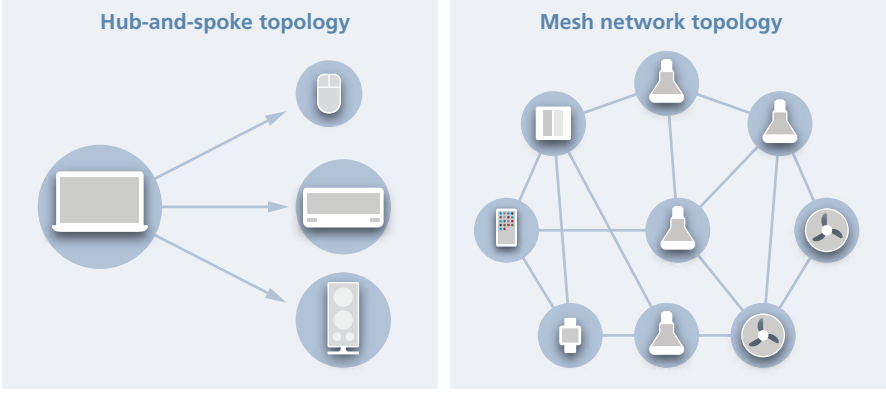

FIG. 2. Legacy Bluetooth has relied on a hub-and-spoke topology while commercial smart lighting will require a mesh network for communications.

The reason why Bluetooth Smart was never considered a serious contender for building automation purposes is because it was designed to support relatively simple hub-and-spoke networks (Fig. 2). Applications like smart lighting require much more than that. Peer-to-peer communication and extended range are among the must-have features enabling a robust network consisting of multiple smart bulbs, and the core specification of Bluetooth Smart simply didn't provide such capability. Its hub-and-spoke model couldn't match with the mesh topology of ZigBee or Z-Wave networks, and for this reason Bluetooth could never really compete with the two in the applications they were intended for.

Is this meshable?

Even though the support for mesh networking wasn't included in the core specification of Bluetooth Smart, several companies noticed that building a mesh network based on this particular communication standard might not be such a bad idea. In 2014, Silvair (operating as Seed Labs back then) started building a mesh architecture based on Bluetooth Smart. Transforming the protocol's single-hop topology into a robust multi-hop, peer-to-peer network was quite a challenge, but the potential reward was enormous.

A mesh network based on Bluetooth Smart also turned out to offer outstanding performance and the core features of the Bluetooth radio allowed us to overcome many of the challenges that other communication protocols have a hard time dealing with. Obviously, the technology developed by Silvair was proprietary, although we did manage to maintain compliance with Bluetooth Smart's core specification.

Having received a fair amount of input from Silvair and other companies working on their proprietary mesh solutions, the Bluetooth Special Interest Group realized that such an opportunity cannot be wasted. In February 2015, it announced the formation of the Bluetooth Smart Mesh Working Group. Its goal was to standardize mesh networking support and incorporate it into the protocol's core specification. Competing companies sat down to share their experiences and find the best way to implement the mesh architecture into Bluetooth Smart. Near the end of 2015, the SIG officially confirmed that it's on track with the development of the Bluetooth Mesh, and that the standard would be adopted at some point in 2016. Moreover, some major improvements with regard to both the data rate and range of Bluetooth Smart will be included in the new standard.

The standardized mesh architecture based on Bluetooth Smart is shaping up to be a powerful framework enabling robust and scalable implementations in some of the most challenging applications. Being part of that development process and seeing many of our concepts being incorporated into the

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global standard is a great feeling. We are currently among the leading contributors to the Bluetooth Smart Mesh Working Group. The details about the upcoming mesh standard remain strictly confidential until some official announcements are made by the SIG itself, but we can provide you with a sneak peek into the basic concepts behind our Silvair Mesh technology, which might give you a good idea of what Bluetooth-based mesh networking is all about.

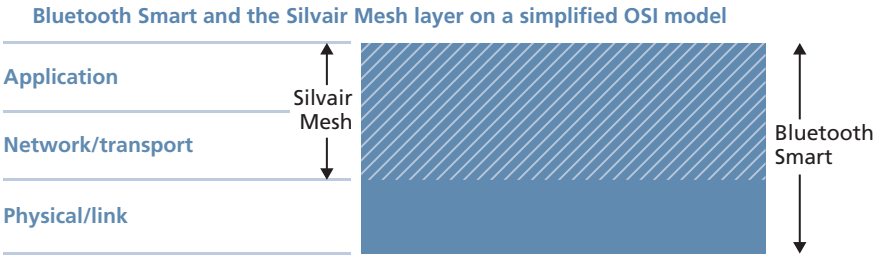

FIG. 3. Smart mesh capabilities are added to Bluetooth devices in the network, transport, and application layers in software and don't impact the physical and link layers that are captured in radio ICs and modules.

Meet a mesh

Silvair Mesh has been developed to allow users to build their smart mesh networks in which one or more mobile devices (smartphones/tablets) can control one or more mesh-enabled peripheral devices (e.g., lamps, sensors, dimmers, switches, etc.). When equipped with the mesh software stack, essentially an enhanced Bluetooth Smart stack, these devices can communicate with each other and the central controller via the Bluetooth Smart radio using the protocol's standard mechanisms called GATT (Generic Attribute Profile). This means that all mesh-enabled peripherals can create their own autonomous mesh network that does not require any central device to operate.

The decision to base Silvair Mesh on Bluetooth Smart was intentional, as it meant that the ecosystem would be compatible with all existing Bluetooth Smart devices and chipsets. However, a mesh stack also requires numerous additional features to standard Bluetooth Smart. For instance, the Silvair Mesh includes a high-performance Bluetooth controller and a new Network Security Manager, as well as the secure OverThe-Air Update functionality, which means that a device can be upgraded to the newest version of the firmware at any time.

Such a carefully crafted mesh software stack can be installed on any compatible Bluetooth chip. Silvair also developed a ref-

erence design for modules to provide the best possible solution for large installations such as those found in commercial buildings. These modules consist of standard Texas Instruments CC254x Bluetooth modules with upgraded firmware, an amplifier, and an antenna. Operating at +10-dBm Tx (transmit) power and with -98-dBm Rx (receive) sensitivity, the modules provide a 108-dB link budget that translates to a range of 1500 ft (about 500m) in the open air. Inside buildings, this value will obviously be much lower and dependent on numerous factors, yet it still remains impressive.

An important thing to realize is that mesh is a purely software solution. This means that Bluetooth Smart chipsets found in today's smartphones can control devices employing proprietary technologies such as Silvair Mesh, and will remain perfectly suitable for controlling and managing mesh networks once the standard is adopted by the SIG. The aforementioned software stack is applied to the networking and application layers of the standard Bluetooth Smart protocol stack as shown in Fig. 3.

How the mesh works

Now let's consider how the mesh extension works. There are two types of communication within a Silvair Mesh network: central to peripheral and peripheral to peripheral. Once the mesh network is commissioned, there is no need for further central-peripheral communication.

Central devices are usually smartphones and tablets. Such devices would typically run some type of control software. In the Silvair case, we developed an app for iOS and Android devices. The central devices are used to configure and manage the network but can also perform a software update of peripheral devices. Central devices connect to peripherals using Bluetooth Smart's standard GATT services. While this type of connection is fully compatible with Bluetooth 4.0, it employs certain proprietary techniques to allow many smartphones to be used simultaneously to control more than eight peripheral devices with eight being the limit in standard Bluetooth 4.0.

Peripheral devices are the nodes of a mesh network. A robust mesh implementation must allow peripherals to talk to each other and act as relays that pass messages through the mesh. This is a radical departure from the original architecture of Bluetooth Smart, and it allows for controlling entire groups of devices using multicast (one to many) communications — e.g., dimming a group of ceiling lights in a hallway. The Silvair Mesh implementation allows a maximum of 63 hops, which enables it to cover very extensive areas out of the box, in contrast to other technologies that require setting up more complicated or more expensive networks.

One of the most significant concepts introduced in the Silvair implementation is connectionless communication, which means that every peripheral can advertise its status in the network. As a result, lights, fans, shades, and any other mesh-enabled device are displayed automatically in the app on the central device, not only as a simple list of available devices, but with very specific parameters that can be controlled by the user — e.g., on/off, color, temperature, fan speed, or shade position. Every status change made by the user is immediately advertised to the network, and every controlling device in the mesh is updated instantly with the new status.

Network setup

As will be required in commercial applications, the Silvair Mesh software allows networks of any size to be set up, but the way in which large and small networks are commissioned, is different. Small networks of up to about 30 devices can be commissioned and managed using just the app on a smartphone or a tablet. The plug-and-play nature of Bluetooth, and the fact that the protocol is natively supported by virtually all smartphones and tablets on the market, makes the entire process extremely simple and intuitive. The app detects and displays mesh devices in its vicinity. The user creates a mesh network by selecting which devices should be added, and by giving the network a name. Once added to the network, associations and relationships can be set up between the devices as desired. The smartphone can then be switched off and these connections will remain in place (Fig. 4).

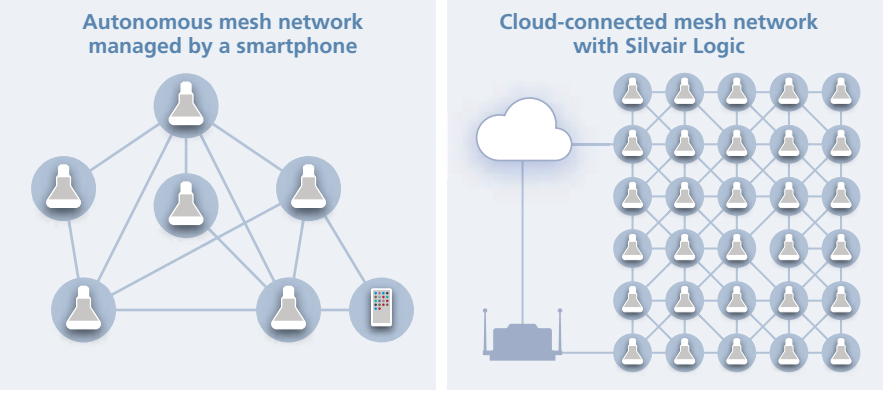

FIG. 4. Silvair Mesh supports both smaller mesh networks controlled by a single smartphone and complex networks with dedicated cloud-connected servers.

Networks of over about 30 devices, or the ones requiring more sophisticated associations, scenarios, and network monitoring services, are best set up using some type of server or management appliance. In the case of Silvair, an embedded server called Silvair Logic hosts all the logic that controls the entire network, checks the status of all peripherals, and reports any issues and unusual events via a browser-based interface.

Other mesh needs

There are a few other key elements of a Bluetooth Mesh implementation that we will mention briefly here. There needs to be a concept of permissions for control devices that ensures proper management of devices in the network. The Silvair software stack implements four levels of permissions: 1) Administrator — can operate all devices within the network, as well as configure them and manage other users' permissions; 2) Family — can operate all devices within the network, but cannot configure or manage them; 3) Guest — has limited permission to operate selected devices within the network; 4) and AdHoc — can operate public devices only on a one-to-one basis (no access to the mesh network).

Likewise, the network nodes or peripherals require the ability to provide information on their operational status and programmability. The Silvair software stack defines three Peripheral Device States: 1) Factory Default — the device leaves the factory in this state and is ready for commissioning; 2) Private — all communication is encrypted, so only users with matching keys can decrypt the state information and control the device; and 3) Public — state information, as well as selected control functions, are not encrypted and can be accessed by anyone.

The Bluetooth difference

The question one might ask at this point is why the Bluetooth Smart mesh would be any better than other mesh protocols available on the market? Simply put, it's all about the radio. Out of all low-power, low-bandwidth communication standards, none is even close to having such impressive qualities as Bluetooth Smart. This allows the protocol to address some of the most difficult issues in such challenging applications as smart lighting, where multicast, synchronous operation and responsiveness are among the must-have features.

We've tested many other technologies inside out, and we know exactly why the existing mesh protocols have failed to deliver the smart lighting experience to environments where reliability and scalability are top priorities. And we firmly believe that this year's adoption of the Bluetooth Smart mesh standard might finally open the door for smart lighting networks to become widely deployed in professional applications.


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focus on

Packaged LEDs

LED architectures advance across package types and applications

Just a few short years ago in the early days of so-called high-brightness LEDs, manufacturers offered a small selection of component options and left it to solid-state lighting (SSL) product developers to meld the components into the target application. Today, LED manufacturers offer products specific to most every application you can imagine, and in fact you can choose from high-power, COB, mid-power, CSP, and other options for the same general-lighting application. We have advancements in white and color components, and for that matter in UV and IR devices that emit outside the human visual range and that promise to enable amazing new SSL applications. Here we will review some of the most significant packaged LEDs announced in the past year with summaries of device characteristics, general device trends, and specific SSL application targets. — MAURY WRIGHT

Samsung Vivid COB LEDs

The chip-on-board (COB) LED-array landscape has proliferated broadly in the past two years, progressing from a product of convenience given the simple electrical, thermal, optical, and mechanical interfaces to products with enhanced optical properties. For example, Samsung brought to market several new COB lines in mid-2015 that have significant white-light and color-quality innovations. Most prominently, the Vivid COB Series is intended to make colors appear, as the name implies, more vivid. In many cases, LED and SSL module makers have used different emitter and phosphor mixes to enhance and even oversaturate colors such as red and blue. Samsung is evidently not oversaturating the colors because the company said the Vivid LEDs would maintain a CRI rating of 90 and oversaturation is penalized in the CRI formula. The company said the Vivid COB LEDs combine improved tuning of the color spectrum and better phosphor control to "depict the red, blue, and green coloration of objects much more clearly." Samsung also added COB devices with smaller light-emitting surface (LES) areas — 6, 8, and 11 mm —to offer higher center beam candle power (CBCP) for directional lighting applications. Indeed, the products are generally 35% smaller at the same output levels relative to prior-generation COB LEDs from the company. Samsung further announced a number of COB LEDs with what it calls Ultra-High Color Rendering, meaning a CRI rating of 95 or better. ◄

Halogen lamp | Vivid Color COB

MORE: http://bit.ly/1QMwk0z

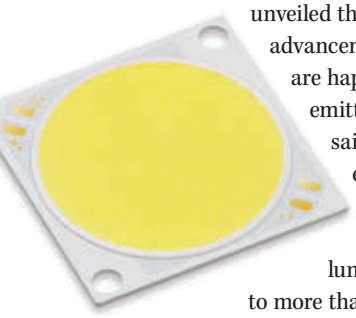
Lumileds Gen 2 Luxeon COB LEDs

Lumileds was first to strike with optical enhancements to a COB architecture when it launched the CrispWhite product back in 2014 for better white and color rendering

(http://bit.ly/1xh4h2Q). In fact, the team behind that product won the 'Illumineer of the Year' award in our *LEDs Magazine* Sapphire Awards program in February 2015. Later in 2015, Lumileds launched the Gen 2 Luxeon COB Core range with LES options ranging from 9–19 mm and in the fall the new COB 1216 that delivers 15,000 lm and is available over the range of 2200K to 5700K CCT. That newest COB LED is targeted at applications such as street and area lights and indoor high-bay luminaires with such SSL products being capable of replacing 100W to 150W high-intensity discharge (HID) lights. The 1216 COB LED features a 23-mm LES and is packaged in a 28×28-mm footprint. The LED delivers an even greater performance increase of 40% than did the smaller Gen 2 LEDs. Such COB LEDs continue to be popular for simple manufacturing and assembly, but increasingly it's the performance and efficiency that will draw many customers. "We continue to push our chip-on-board technology to higher efficiency, which is important in all applications but particularly in outdoor fixtures," said Eric Senders, product line director for COB LEDs at Lumileds. "With the new line of arrays, customers are achieving 150 lm/W at nominal condition, which, combined with our lowest-in-the-industry thermal resistance, leads to the most cost-efficient systems." ◄

MORE: http://bit.ly/1RRTyr2

Citizen CLU550 COB LEDs

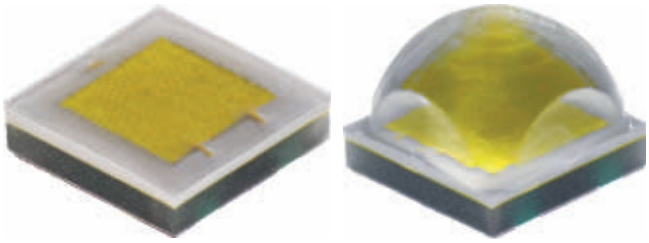


Citizen Electronics is also a player in the COB LED space. At the Hong Kong International Lighting Fair in the fall of 2015, the company unveiled the CLU550 family. The new LEDs show the advancements being made in COB packaging that are happening in parallel with advancements in emitter architecture and performance. Citizen said it was able to increase the number of emitters integrated in the COB LEDs by 45% in the same physical space relative to its prior-generation COB product. Typical lumen output went from just under 57,000 lm to more than 70,000 lm. The CLU550 LEDs come in a 38×38×1.4-mm package and in 70- and 80-CRI models. Citizen said the new LEDs enable brighter luminaires or the development of smaller luminaires that rely on a single brighter source. ◄

MORE: http://bit.ly/1Ttd3XV

Cree XHP35 LED Series

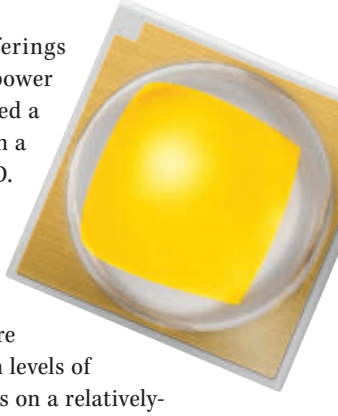
In the traditional discrete high-power packaged LED area, Cree continues to set the performance pace whether the implementation uses one or multiple-arrayed emitters. In mid-2015, Cree announced the XLamp XHP35 family of packaged LEDs that includes products in both High Density (HD) versions with a domed primary optic and High Intensity (HI) versions with a flat primary optic. The new products marked the introduction of what Cree calls the SC5 (silicon carbide 5) technology platform being fully utilized in an LED in the 3.45×3.45-mm form factor, or what Cree calls the XP footprint based on prior packaged LEDs such as the XP-G/G2, XP-L, and XP-E/E2.



The XHP35 LEDs output a maximum 1833 lm from a single emitting surface, putting the LEDs in a class with multi-die LEDs in discrete packages but without the optical inefficiency of multi-die LEDs. Cree offers the LEDs across the range of 2700K to 8300K in CCT; in 70-, 80-, and 90-CRI flavors; and in 2- or 3-step MacAdam ellipse bins. Customers are using the new LEDs and footprint legacy to upgrade existing SSL products with the simple change of an LED. "We're excited that the XHP35 LED brings the performance of Cree's Extreme High Power LEDs to the XP footprint," said Jorge Fraile, CEO of Hispaled. "In addition to delivering an impressive amount of light, the XHP35 LED allows us to leverage existing drivers to achieve the full performance of Cree's high-power LEDs at lower drive currents." As for the HI and HD flavors, Cree uses the term HD to describe discretely-packaged and COB LEDs that offer what the company calls better optical control factor (OCF), essentially touting the better beam control achievable with more flux from a smaller source. See a description of the HI concept in coverage of the XQ-E LED series later in this article. ◄

MORE: http://bit.ly/1oNFYtg

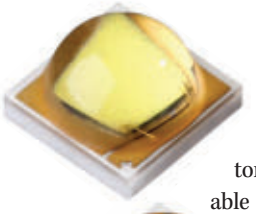
Samsung LH351B LED



Samsung is proliferating its LED offerings across the COB, high-power, and mid-power LED spaces. In 2015, the company achieved a major upgrade in performance levels with a new version of the venerable LH351B LED. Efficacy hit 173 lm/W at 85°C temperature and 350 mA of drive current — an 8% improvement over the prior year. The LED utilizes Samsung's proprietary TZ chip structure and PSS (Patterned Sapphire Substrate) technology to achieve the high levels of performance. Moreover, the LH351B relies on a relatively-unique film phosphor for conversion that Samsung claims improves color stability. The LED has an expected lifetime of 280,000 hours when operated at 105°C and 1A. ◄

LG Innotek H35C4 LED Series

In the fall of 2015, LG Innotek announced the H35C4 high-power LED Series with what the company claimed at the time to be the highest efficacy on the market. The 3.5×3.5-mm high-power LEDs can be driven at up to 5W and are squarely targeted at high-output general-lighting applications such as street lights and high-bay fixtures. The new packaged LEDs arrived with a maximum efficacy claim of 180 lm/W when driven at 350 mA and forward voltage rated in the 2.7V to 3V range. The company stated that the maximum efficacy was 10%



higher than any competitive high-power LED products from other manufacturers and 13% better than its prior offerings in a similar form factor. At 700 mA, the efficacy drops to a still respectable 152 lm/W at a junction temperature of 85°C. It's always hard to evaluate manufacturers' claims about superior LED performance because there are so many variables in play; often, stated maximum performance specs may not be at realistic use conditions. The Cree XHP35 would appear to be a bit ahead, but the LG product is in the ballpark. LG said it achieved the performance of the H35C4 through a vertical LED architecture and an optimized mixing process in the phosphor materials that create the white light. The vertical characterization implies a flip-chip approach in which the emitting surface was originally adjacent to the growth sapphire. The new LG packaged LEDs also come with LM-80 test data that suggests a life of 150,000 hours. ◄

MORE: http://bit.ly/1kdT3tT

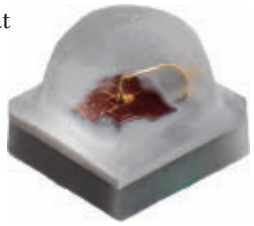
Samsung LM561B+ and LM561C LEDs

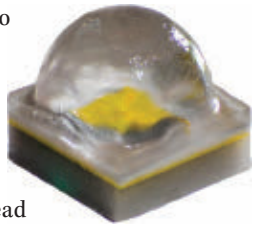
The trend toward mid-power LEDs in many general illumination applications was a prominent theme over the past year. Generally, mid-power LEDs cost less than high-power alternatives and while more devices are required to deliver a given lumen requirement, the mostly surface-mount device (SMD) components are assembled using automated equipment. Moreover, efficacy levels exceed those found in many higher-power devices. For example, Samsung recently announced the LM561B+ and LM561C 0.3W LEDs that extend efficacy to the 200-lm/W level. Such products are also delivering tighter color- and lumen-maintenance tolerances. The new LM561B+ is more focused on color attributes while the LM561C delivers maximum performance. Samsung is offering the LM561B+ LEDs in 3-step MacAdam ellipse bins and quarter bins in CCTs ranging from 2700K to 6500K. Moreover, the company said it has a new phosphor-control technology that will yield 90-CRI LEDs with 15% higher flux output at 90 CRI. "To date, we have achieved outstanding performance in all of our mid-power LED packages," said Jaewook Kwon, vice president for the Lighting Marketing Group at Samsung Electronics. "By now offering premium light quality to a greater number of customers with our LM561B+ LED package, we are able to provide superior performance on a much wider scale." While the LM561B+ LEDs max out at 190 lm/W, the new LM561C LEDs hit the 200-lm/W level. Samsung said it will bring the tighter color control to the LM561C family later in 2016. The company first introduced the LM561B family at 160 lm/W in early 2013 (http://bit.ly/1Kt3QMP), with those LEDs offering a 30% performance upgrade over the prior LM561A LEDs. ◄

MORE: http://bit.ly/1PK7qUJ

Cree XQ-A Series

Cree remains a holdout from the plastic-packaged mid-power LED trend, although the company does enjoy access to such LEDs via its investment in Lextar (http://bit.ly/1FAFonY). But for its own packaged LED portfolio, Cree has focused on developing very small LEDs that are still delivered in ceramic packages with high-power operational characteristics. The Cree XLamp XQ-A LEDs extend the XQ family with mid-power alternatives that the company said offer better reliability and more consistent lumen-output and color performance. Some of the applications will also come in industrial settings. "The introduction of the XQ-A LED gives us more options to increase the capability of our machine-vision and industrial LED lights using the same compact XQ package that we know and like," said Matt Pinter, co-founder and lead design engineer for Smart Vision Lights. "Unlike mid-power color LEDs, the compact, ceramic-based XQ-A LED will allow us to put two, three, or even four LEDs under our new silicone lens technology where we could only use one LED before. This generates more light for industrial applications without compromising lifetime." The XQ-A outputs 89 lm at 1W maximum in phosphor-converted white flavors. Cree offers the white LEDs across the 2700K- to 6200K-CCT range with 70-, 80-, and 90-CRI options. The company also offers color versions available in monochromatic red, red-orange, green, blue, and royal blue along with phosphor-converted amber. ◄





MORE: http://bit.ly/1PK7qUJ

Everlight 5630KK5D and 5630KK6D LEDs

The industry-standard 5630 LED package (5.6×3.0-mm) is among the most popular of mid-power options and many companies offer such LEDs. For white SSL applications, Everlight Electronics has new LEDs in the 5630 package that push efficacy to the 200-lm/W level, targeting both retrofit lamps and luminaires. These Everlight LEDs are intended for operation more akin to traditional mid-power levels at 0.2W. The company has announced two new products. The 5630KK5D delivers 195 lm/W at a 5000K CCT and shipped a bit earlier than the 5630KK6D that delivers 205 lm/W at a 5000K CCT and came to market in late 2015. Everlight said the improved performance enables SSL manufacturers to substitute the new LEDs into existing product designs with no printed-circuit board (PCB) or optics changes, and realize significant performance improvements. Alternatively, development teams can deliver new product designs with fewer packaged LEDs when specifying the new products. Everlight said a 2000-lm finished product would

consume 11W or less. Everlight also noted that it achieved the new performance levels using plastic materials with high-reflection and improved optical structures, and that the LEDs would deliver the long lifetimes needed in applications such as commercial lighting. ◄
MORE: http://bit.ly/24d50aC

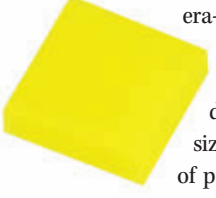
Edison Opto PLCC 2835 NE Series

Still, much of the development in mid-power LEDs in the recent past has been focused on lower-cost components that can reduce the bill of materials in a lighting product despite the use of more lower-brightness LEDs. Indeed, Edison Opto, faced with what it characterized as chaotic price wars, has been striving to introduce more

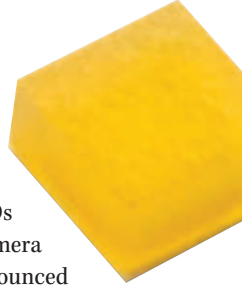
high-efficiency packaged LEDs in order to build a strong market position. One of its new product lines is the PLCC 2835 HE Series packaged LEDs. It features 185lm/W luminous efficacy at a 4000K CCT. Moreover, the compact package size increases flexibility in lamp design and expands the range of applications in which the LEDs can serve. In addition, Edison Opto added products in the 5630 packaged LED space. The advanced PLCC 5630B HE Series offers 188 lm/W efficacy at 4000K CCT and reaches 34 lm at 65 mA of drive current. Both of the PLCC families have undergone LM-80 testing. ◄
MORE: http://bit.ly/1VqAK11

Seoul Semiconductor WICOP LEDs

The next evolutionary step for packaged LEDs is thought by many to be the elimination of the package with the move to what is called a chip-scale package (CSP). We ran a feature article in September 2015 that explained the theory behind the CSP and the potential for lower component cost (http://bit.ly/1Kt4OIW). Seoul Semiconductor has become among the first manufacturers to enter mass production of CSP LEDs in what the company calls WICOP (wafer-level integrated chip on PCB) LEDs. The new LEDs designed specifically for general illumination are being called WICOP2, differentiating the new products from earlier WICOP LEDs that have been sold in backlighting, automotive, and camera-flash applications. Seoul was bold in its announcement that questioned investments other manufacturers are making in packaging lines. "Through the development of WICOP, which is an innovative small-sized, highly efficient LED technology, the effective value of packaging equipment which was once essential in semiconductor assembly process will noticeably decrease," said Kibum Nam, head of the central research center at Seoul Semiconductor. "As all of the parts which had been used for more than twenty years will not be necessary anymore, there will be a huge change in the future LED industry." CSP technology will be of greatest benefit to the lighting manufacturers that can afford the required automated assembly equipment and that can pack the LEDs tightly in some products or essentially use the luminaire frame as the substrate in products such as linear lighting and troffers. Seoul Semiconductor will supply WICOP2 LEDs into mid-power-LED applications at least initially and that's the target for most CSP providers except for Lumileds, which is applying CSP at the high-power level. ◄
MORE: http://bit.ly/24d6GvE



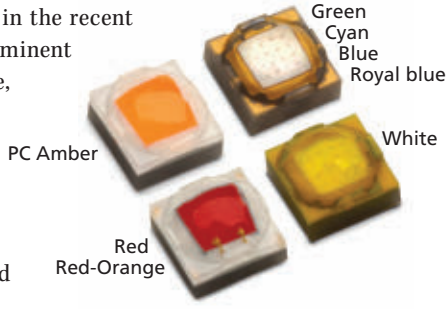
Lumileds Luxeon FlipChip White LED



Lumileds was the first manufacturer to announce a CSP LED back in early 2013 at Strategies in Light (SIL) when it launched blue-pump LEDs with no phosphor (http://bit.ly/1foX4lz). At SIL in 2015, the company said it shipped more than a quarter-billion CSP LEDs during 2014 into backlighting, automotive, and camera flash applications. In the fall of 2015, Lumileds announced the Luxeon FlipChip White LEDs for general illumination applications. The LEDs will come in 1.4×1.4- and 1.1×1.1-mm footprints and are available over a color temperature range of 2700K–4000K CCT. Lumileds will offer the LEDs in a choice of 70 or 80 CRI. Efficacy is as high as 124 lm/W when driven at 175 mA for the smaller LEDs and 139 lm/W when driven at 350 mA for the larger LEDs, both at 85°C. The CSP LEDs do not integrate a primary optic and will emit on five sides, delivering a wide beam angle that's ideally targeted for products such as low- and high-bay luminaires. The new CSP LEDs will also be available on Matrix LED light engines in PCB form for customers who lack the manufacturing equipment to install the CSP LEDs. That family includes both linear and flexible models and optionally can include other elements needed in a luminaire design such as optics and electronics. ◄
MORE: http://bit.ly/1KQ1wiV

Lumileds Luxeon C color LED Series

The 2015 calendar year saw a resurgence of interest in color LEDs, both monochromatic and phosphor-converted colors, and in fact we published a feature article on the topic (http://bit.ly/1YlkHaf). It wasn't so much that color LEDs haven't been widely used in the recent past because they are prominent in vehicle lighting, signage, and tunable color lighting. But in 2015, several prominent players refreshed their color product lines and brought advancements pioneered



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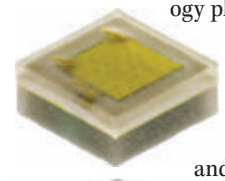
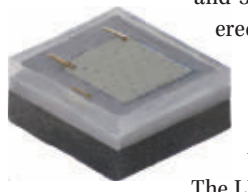
in white LEDs to the space. Lumileds, for example, announced the Luxeon C family of monochromatic- and phosphor-converted-color LEDs to market, leveraging some of the latest epitaxial, packaging, and optics technologies from white high-power LEDs. The new family includes a low-profile primary dome-shaped optic for more center punch and the optic height is consistent relative to the emitting surface on all LEDs in the family for precise color mixing. The Luxeon C family includes 12 color LEDs plus white LEDs in six different CCTs. The Luxeon C announcement followed the roll out of the Luxeon 3535L mid-power color family (http://bit.ly/1JdUKM7). Lumileds also became the first manufacturer to hot test and bin color LEDs at 85°C with the Luxeon C family. Such testing is critical to consistent performance at temperature both in terms of the wavelength shift of each emitter and in intensity shift. ◄

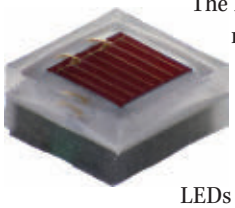
MORE: http://bit.ly/1KxS2Tu

Cree XQ-E Series color LEDs

Not long after Lumileds revealed the Luxeon C family, Cree announced an upgraded XLamp XQ-E packaged LED product family applying its High Intensity (HI) feature set to color LEDs and a new white LED. The new products are based on the SC5 (silicon carbide 5) technology platform and are offered in white, red, red-orange, phosphor-converted amber, green, blue, and royal-blue versions for SSL applications such as architectural façade lighting. The new Cree XQ-E HI white LEDs deliver 334 lm at 1A of drive current and 3W compared to an earlier product that delivered 287 lm (http://bit.ly/1Q7yGLT). Still, the performance improvement is more significant than evident strictly from a luminous flux comparison. The HI concept came to market in 2015 in the XP-L product family (http://bit.ly/1EExWmA). The LEDs use a relatively flat primary optic that ultimately enables a tighter beam and better punch or center beam candle power (CBCP). The Cree LEDs come in a smaller 1.6×1.6-mm form factor relative to the 2×2-mm Lumileds Luxeon C family. Lumenpulse is one company that uses color LEDs in luminaires intended for façade or grazing applications, and that commented on the new Cree products. "The XQ-E High Intensity is a perfect tool in our toolkit to maximize candela output for our innovative products," said Greg Campbell, senior vice president and CTO at Lumenpulse. He further emphasized the importance of CBCP, adding, "At Lumenpulse, candela is the name of the game, and we want to put as much light as possible on the surface we are illuminating, as efficiently as possible." ◄







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Osram Duris S 5 Color LEDs

Osram Opto Semiconductors has arguably the widest selection of color LEDs, as you will surmise if you peruse the aforementioned feature article on the topic. Most recently, the company announced the Duris S 5 Color LED portfolio positioned in the mid-power space and intended for application alongside phosphor-converted white Duris packaged LEDs in general lighting products with color mixing capabilities. The Duris S 5 Color portfolio includes packaged LEDs in four colors — red, amber, green, and deep blue. The new 3.0×3.0-mm LEDs come in an epoxy-based package designed to enable reliable operation and good color and lumen maintenance at relatively higher drive currents. The dual-emitter designs have a typical 6.2V forward voltage and are rated at 150 mA. That near-1W operating level has only in the past couple of years become common for mid-power LEDs. Efficiency is difficult to quantify with color LEDs because the normal efficacy (lm/W) metric is based on the characteristics of the human eye and is meaningless in products such as blue and even red LEDs. But Osram says the green LEDs deliver 170 lm/W. Osram realized all of the Duris S 5 Color LEDs via phosphor conversion. The baseline LED chips are identical for all colors. The phosphor-converted approach can yield higher efficacy across the color range and the LEDs in all colors should have the same projected lifetime and identical focal lengths. ◄

MORE: http://bit.ly/24d50aC

LED Engin LZP LEDs

RGB LEDs targeted at entertainment and projection applications represent a niche within the broader subject of color LEDs. Generally, such LEDs are very-high-power devices and often have red, green, blue, and possibly other-color emitters integrated in one package. LED Engin is one key player in the entertainment and dynamic-lighting space and announced what the company said was a new world record in both flux and power density for high-power, multi-color LED lighting in late 2015. The LZP family of red, green, blue, and cool white (RGBW) LEDs can deliver 3800 lm from a 12×12-mm footprint. The 25-die, 80W LEDs have a 6.2×6.2-mm light-emitting area. The LZP LEDs now give designers of LED entertainment and architectural lighting the freedom to create more powerful yet slimmer, very compact lamps in innovative new styles that appeal to customers. Developers can buy the LZP products in two package options. A domed version is typically used with a secondary total-internal reflection (TIR) lens while a flat version provides compatibility with more-complex secondary optics such

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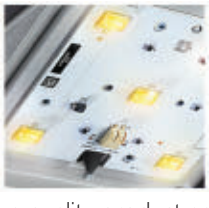

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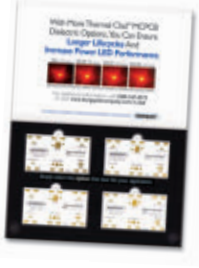

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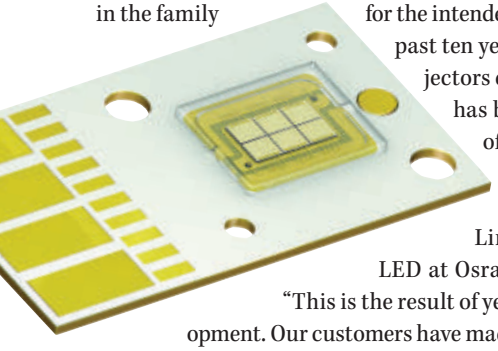
as zoom lenses that might narrow the output beam to 10°. "We're dedicated to developing LED products that enable lighting designers to express their creativity and produce better products for their customers, particularly in the competitive and highly demanding entertainment lighting sector," said David Tahmassebi, LED Engin's CEO and president. Three of the LZP LEDs can deliver 10,000 lm or the equivalent of a 700W HID lamp. ◄

MORE: http://bit.ly/1WuC43f

Osram Ostar Power Projection LEDs

Indeed, packaged LEDs continue to find use in digital projection applications for settings ranging from conference rooms to entertainment venues. Osram is a key player in that space and recently announced new LEDs in the Ostar Projection Power family. The company said the new P3W 01 and P3A 01 LEDs will enable mainstream projectors to output 2500 lm. The company offers monochromatic red and blue, and phosphor-converted green LEDs in the family for the intended RGB application. "In the past ten years, the brightness of projectors equipped solely with LEDs has been increased by a factor of 100, since the first LED projector launched by our partner," said Andrew Lin, product marketing for LED at Osram Opto Semiconductors. "This is the result of years of research and development. Our customers have made huge progress in system development, while we continue to improve chips and packages." Each of the color LEDs in the new packages integrates six smaller emitters with an area of 2 mm². The devices are based on the Osram UX:3 thin-film technology platform. UX:3 ensures uniform current spreading, enabling the high output required in applications such as projectors. The red LED is rated at 4500 lm, the green at 11,000 lm, and the blue at 33W of radiometric power. ◄



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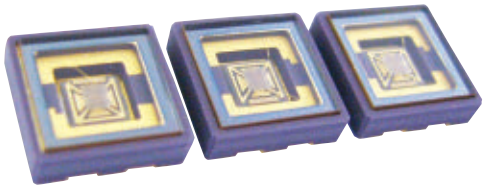
Nikkiso DUV LEDs

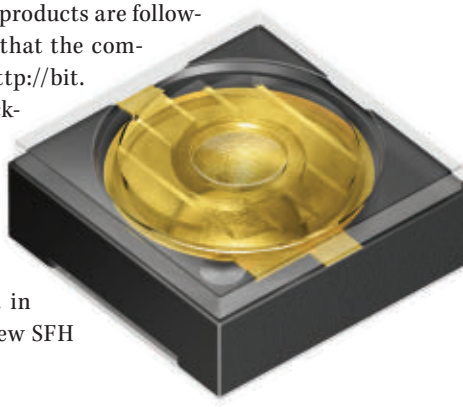
While LEDs that produce visible light, and most often white light, receive the most interest within the SSL industry, devices that operate outside the visible range in the ultraviolet (UV) or infrared (IR) bands are also enabling many new applications. Moreover, industrial, life science, medical, consumer, and other applications that can use UV or IR LEDs leverage similar energy-efficient, small-source-size, and longevity benefits that have driven visible-light LEDs to success in lighting. Nikkiso America, for instance, recently announced the general availability of 50-mW deep-ultraviolet (DUV) LEDs that the company said have operating lifetimes in excess of 10,000 hours. The evolution of UV-LED technology at shorter wavelengths holds great potential for applications ranging from industrial curing to water sterilization. UV-LED manufacturers, however, have struggled to deliver high-power, long-life, and cost-effective LEDs, especially in the UV-C or deep-UV range. The latest Nikkiso UV LEDs address the issue of delivering useful levels of radiometric power in a small packaged LED. The company said the 50-mW output at 350-mA of drive current is 1.7 times the power of its prior generation products. That performance level combined with the long-life expectation is seen as key to commercial success in UV LEDs. "UV-LED technology is advancing rapidly, with extraordinary progress reported annually in optical output power, efficiency, and cost," said Dennis Martin, president and CEO of Nikkiso America. "Whether the application involves curing, medical, germicidal, or analytical instrumentation, deep-UV LED technology offers compelling advantages over lamp-based solutions and further enables new applications." ◄



MORE: http://bit.ly/1Kt6j9S

Osram Oslux SFH 4786S IR LEDs

While UV LEDs support applications such as sterilization and curing, IR LEDs are being used in range finding, night vision, and consumer electronics. The Oslux SFH 4786S IR LEDs (Osram calls them IREDs) squarely target biometric identification applications in devices such as smartphones and tablets. Iris scanning allows owners of a device to simply gain access while sensitive data is protected from others. The new products are follow-on components to IR LEDs that the company announced in 2014 (http://bit.ly/1PJ93it). Both the new packaged LEDs and the prior SFH 4780S family are optimized for light extraction that is necessary for generating an iris image that can be acquired by the camera in a phone or tablet. But the new SFH



4786S is lower profile, measuring 1.6-mm high whereas the prior product was 2.4-mm high. The more compact design enables usage in thinner phones and tablets. The new LED also features an 8° tilt in the emission direction. Osram says the "slightly sideways" beam matches the typical field of view of a camera in terms of how users hold such devices. "Up to now, mechanical means have been used in iris scanners to tilt the IRED slightly," said Chris Goeltner, IR product marketing manager at Osram. "However, this additional expense is no longer needed with the SFH 4786S. This greatly reduces the level of complexity in designing iris scanners." Osram also introduced the IR Oslon Black LED in 2015 that is designed for use in near-range illumination for camera surveillance (http://bit.ly/1oTiH9A). The 850-nm LEDs have a 100m range. ◄

MORE: http://bit.ly/1Zg8xwz

Crystal IS Optan UV LEDs

Back in the UV-LED space, Crystal IS offers a range of such LED products in SMD and through-hole packages with the latter including both TO-39 packages with a dome lens and with a flat window on top. The newest Optan UV-C products deliver longer life, greater light output, and lower power consumption. Target applications include biofouling control and Total Organic Carbon monitoring in water to safeguard industrial water purification systems. The

SMD version is the newest member of the Optan family and those devices are especially suited for use in scientific instruments in the aforementioned applications. "Our customers came to us with a difficult situation in controlling biofouling, where coatings, traditional UV lamps, or mechanical wipers weren't that effective," said Larry Felton, CEO of Crystal IS. "We are thrilled that our latest Optan product will solve that problem, especially when it comes to ocean and industrial process instrumentation." The LEDs can also be used as a low voltage source of UV-C light for calibration of cameras, photodetectors, and more.

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IES TM-26 prescribes LED failure rate projection

JIANZHONG JIAO describes how new methods for projecting catastrophic LED failures can lead to SSL product manufacturers' ability to accurately set warranties, and for users to have informed expectations about product reliability and life.

The Illuminating Engineering Society (IES) has published yet another Technical Memorandum (TM) for use by the LED industry and solid-state lighting (SSL) developers. The TM-26 document describes several methods by which developers can project catastrophic failure rates in LED sources. Such failures combine with lumen maintenance to accurately characterize the reliability and expected lifetime of LED-based products.

In the October 2011 issue of *LEDs Magazine*, we published an article titled "Understanding the difference between LED rated life and lumen-maintenance life" (http://bit.ly/1TUXt6F). That earlier article pointed out the difference between an LED's lumen-maintenance life and its rated life. Prior to LEDs, rated life for light sources traditionally included catastrophic failure, in which the light sources no longer produce light.

LEDs do fail catastrophically, though the rate is much lower compared to other light sources. When designing LED lamps or luminaires, the requirement of LEDs' lumen-maintenance life aside, it is also important to know the LEDs' catastrophic failure rate. The reliability and associated warranty for an LED lighting product is essentially based on both the LEDs' lumen-maintenance life and the catastrophic failure rate. The calculation of catastrophic failure rates is an important metric in assessing the reliability performance of an LED lighting product. This failure data can be used as a benchmark for future performance or an assessment of past performance, which may present a need for product or process improvement.

Testing committee work

During the timeframe in which the aforementioned article was published, the IES Testing Procedures Committee (TPC) formed a working group to develop a document addressing the projection of LEDs' failure rate. IES TM-26, "Methods for projecting catastrophic failure rate of LED packages," has just now been published, after more than four years of hard work.

Catastrophic failure rates for LED packages are typically in the range of parts per million hours or parts per billion hours of operation. In the semiconductor and electronics industry, component-level failure rate often refers to empirical population failure rates. Such rates change as components age over time; and the general failure rate trends can be summarized by a graph or a curve. Due to the bathtub-like shape of the failure-rate curve, it has become widely known as the "bathtub curve." In reviewing the industry's practices, the IES TPC working group decided to use the bathtub curve as the basis for describing LEDs' failure rate (see figure).

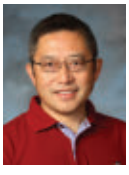
The bathtub curve includes three periods: early failure period, stable failure period, and wear-out failure period. In the early failure period, LED products may be characterized by a rapidly decreasing catastrophic failure rate. Based on the manufacturing experience, the typical catastrophic failures that occur during this period of time may be caused by material defects. The early failure period may typically last several hours to a few hundred hours. LED manufacturers usually use the screening, or product burn-in period, to reduce the duration of the early failure period.

After the early failure period, the failure rate levels off and remains relatively constant, in typical cases, for the majority of the useful life of LEDs. In this long and relatively constant failure-rate period, the probability of catastrophic failure can be modeled by the exponential cumulative distribution function over time. If LEDs remain in use long enough, the catastrophic failure rate begins to increase as materials wear out, and degradation failures occur at an ever increasing rate, which is the wear-out failure period.

Projection models

In general, a reliable projection or prediction model for catastrophic failures over time should be based on experimental observations. The Weibull statistical model is a widely used empirical model; other mathematical models based on device physics can sometimes be a better fit to the data. All best fit models shall be based upon statistically significant sample populations such as typical manufactured parts, well-established reliability methodologies, and validated mathematical models based upon device physics. Experts

DR. JIANZHONG JIAO, *an internationally recognized lighting expert, is an independent consultant for LEDs and lighting technologies. He has been actively involved in LED and LED lighting standard development activities, technical conferences, and industry consortia.*



Currently he serves on the IESNA Testing Procedures, Roadway Lighting, Computer, and Light Source Committees. He is also vice chair of the ANSI SSL Light Source Working Groups, and at present works with many other technical organizations, groups, and symposia, in addition to being a member of the Technical Panel of Strategies in Light. He can be reached at j_jiao@hotmail.com.

in the IES TPC reviewed all available methods of LED failure-rate projections in practice in the industry, and established recommendations based on these commonly used methods. To help both LED producers and the users, TM-26 listed three recommended methods for projecting LED failure rate.

The first method is to report the catastrophic failure rate based on an LED manufacturer's statistical data. Statistical data can be accumulated from field data or quality management information. Without using any specific model, provided the LED manufacturer has sufficient information regarding LEDs' failure rate from its statistical data, such data can be reported and used as the projection for its product datasheet. Because LEDs' failure rate can be related to its case or junction temperature, as well as its forward current, the reported failure rate should include a given case or junction temperature and a given forward current.

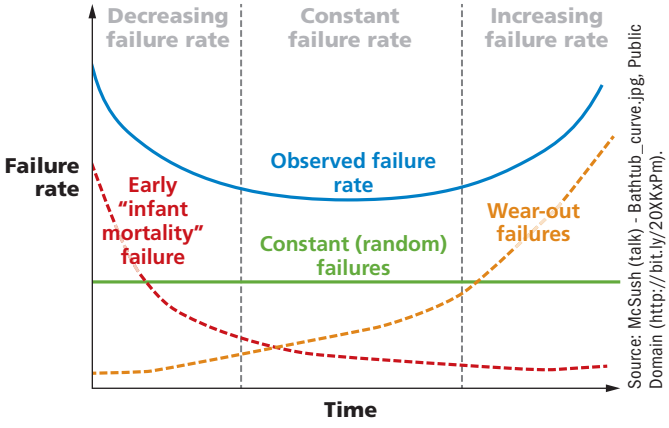
The failure rate is usually the catastrophic failure in units per one billion hours of operation as stated previously. Using this method, LED users can have an overview for the LED package failure rate. For example, an LED package has 1000 failure units per one billion hours of operation at 105°C and at its maximum forward current. If an LED luminaire is designed to use 100 LEDs at the specified temperature of 105°C and the maximum forward current, then ten of these LED luminaires may fail (assuming one LED failure is equivalent to one luminaire failure) per one million operation hours.

Further, if these luminaires are designed to be operating for 50,000 hours, and 20 luminaires are used in one project, then it is predicted that at the end of 10,000 hours, there will be one luminaire failure in this project. When the luminaire manufacturer is establishing its quality claim or warranty policy, this information can be imperative to users.

Empirical model

The second method uses an empirical model that is utilized in the semiconductor and LED industries. This model first establishes a reference failure rate at a reference temperature and a reference forward current — for example, 55°C and 50% of maximum current, respectively. This reference failure rate is also typically determined based on production quality or usage data.

In real-life applications, the failure rate is related to the reference failure rate, which multiplies a temperature stress factor and a current stress factor. For the temperature-dependent stress factor, the mathematical expression is provided in TM-26, and is based on the activation energy of the LED from empirical data, which is a property of the LED die material and structure. For the current-dependent stress factor, the method uses a mathematical expression that is again based on the empirical data.



The "bathtub curve" hazard function (blue, upper solid line) is a combination of a decreasing hazard of early failure (red dotted line) and an increasing hazard of wear-out failure (yellow dotted line), plus some constant hazard of random failure (green, lower solid line).

In a real-life driving-current situation, the ratio of the operation current versus the reference current is presented with coefficients. These coefficients that are also based on the empirical information are provided in the method. When using this method, the stress factor of temperature dependence and stress factor of current dependence can be obtained from TM-26 once the operating temperature and current is designed, then the failure rate associated with the real-life temperature and current can be projected. When an LED-based product is used in a different LED lamp or luminaire design, with each corresponding real-life temperature and current, a failure rate can be calculated, respectively.

Military influence

The third method provided by TM-26 is an approach similar to military standards. For the temperature stress factor, a mathematical expression for failure in time (FIT) is provided. Real test data, including number of devices tested, number of catastrophic failures presented during the test, and equivalent device operation hours are the parameters used in the expression. In conjunction with a defined statistic distribution, including degrees of freedom and the degree of confidence level, the expression can be used to calculate and project the failure rate. The temperature stress factor associated with the LED activation energy is integrated for the duration of the test. For the current stress factor, the Eyring model is recommended and the expression is provided.

As stated in the TM-26 scope, "the three methodologies presented are for information only and do not represent a complete set of methodologies in existence; these represent the methodologies that are publicly available, and have been made available, for publication by the IES." TM-26 provides reference information that allows LED producers and users to communicate in regard to the product reliability measure. If the failure-rate projection methods for LED packages are available, the catastrophic failure rate of LED modules or arrays can also be determined either by summation of the catastrophic failure rate of each individual LED package, or directly at the LED array or module level using the methods described in TM-26.

The work accomplished by the IES TPC experts will add value for LED adoption in the lighting industry. Using LM-80 test data and the TM-21 calculator, the LED lumen-maintenance life can be projected. Now, with TM-26, LEDs' catastrophic failure rate can be projected. The combination of these tools should give LED lamp and luminaire manufacturers higher confidence levels to more accurately project product reliability, and product reliability will certainly benefit the LED end users.

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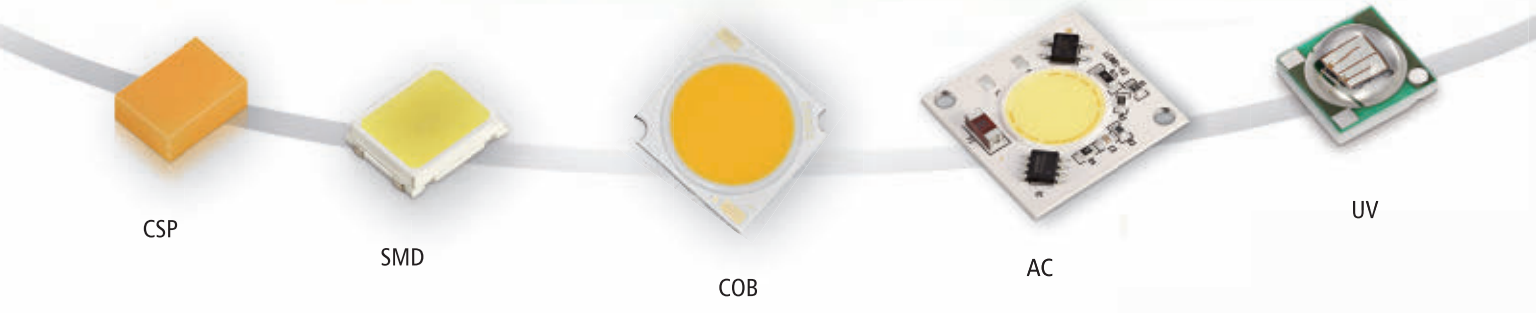

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Second annual Sapphire Award winners exemplify advances in SSL technology

At the *LEDs Magazine* Sapphire Awards Gala Dinner in Santa Clara, CA, held during the co-located Strategies in Light and The LED Show events, true gems of LED-centric innovation were rewarded with a trove of sparkling trophies. **MAURY WRIGHT** and **CARRIE MEADOWS** report on how the winners stood out in this year's excellent lineup of LED technology leaders.

LEDs Magazine hosted the second annual Sapphire Awards Gala on Mar. 2, 2016, recognizing the top innovations over the course of 2015 in the LED and solid-state lighting (SSL) sectors. The Gala was held coincident with the Strategies in Light and The LED Show conferences in Santa Clara, CA. The evening celebration included poignant moments such as a video that reflected on the advances in lighting such as connectivity, and that pointed out the disconnect that remains in making advanced LED-based lighting easy to commission and use. The Sapphire winners later proudly hoisted their trophies and were interviewed for a video that has been posted on our Sapphire web page. Still, everyone in the packed house of industry luminaries enjoyed a festive night with top entertainment, great food and drink, and a chance to network with their peers.

The Sapphire Awards remain unique in the industry as we bestow recognition across a broad technology space. Our categories include both enabling technologies that are building blocks of general lighting and other SSL products, and end products including lamps and luminaires in a number of categories. Moreover, we recognize test and service offerings, and LED-enabled products in specialty areas in industrial and scientific applications.

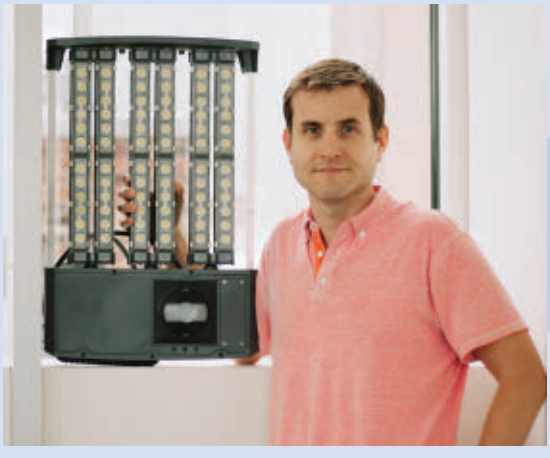
Companies working across the LED and SSL sectors nominated well over 100 products to the Sapphire program, along with individuals or small development teams for the top 'Illumineer of the Year' award. Our Sapphire judges ultimately considered products across 15 categories ranging from packaged LEDs and OLEDs to other enabling technologies to SSL lamps and luminaires. We published a short list of the finalists in each category in our February issue and on the website in a slideshow (http://bit.ly/1QuhwDh). On Gala night, the best-of-the-best took home the Sapphire trophies after a spirited late-night celebration.

The Sapphire judging panel faced a formidable task with far more outstanding products to consider than could receive finalist or winner recognition. Moreover, the products entered are not easily compared directly even within the 15 separate categories that we identified. We challenged the panel to consider each entry on its own merits, and to judge the entries essentially relative to what might be a perfect SSL product in the intended application.

Again this year, we used a scoring system of 0–5 Sapphires. For a product to achieve a score of 3 Sapphires, the judges were tasked with determining if the lighting product or enabling technology would be suitable for deployment in a commercial application. To achieve higher scores, products were scrutinized for how the engineering and innovation leveraged the benefits of SSL to perform beyond the scope of what has been possible with legacy light sources.

To protect the integrity of the program and to ensure the judging panel is never pressured by entrants in the Sapphire Awards, we will not reveal which judges worked on evaluating which entries. We did take steps to make sure that no judge worked in a category where there was any potential conflict of interest.

As we did last year, we will shortly publish a longer list of the entries on our website including all entries that received a score of 3.5 Sapphires or better. Moreover, we will provide a score privately for every entry, along with some of the judges' anonymous comments. We encourage all



Illumineer of the Year Brian Chemel of Digital Lumens.

entrants to publicly post their scores in their own collateral and on their websites.

Illumineer of the Year

Acuity Brands Lighting Gotham Incito 2" Family.

We will start this description of the Sapphire winners where the Gala ended, with the naming of the 'Illumineer of the Year.' This award recognizes a team or individual who has developed an especially noteworthy LED-centric innovation that has the potential to enable higher-quality lighting products with lower product and/or operational costs. The judging process took into account both a quantitative evaluation of the technology for which the entrants were nominated and a qualitative judgment of the contribution that the Illumineer finalists have made in furthering the SSL revolution.

This year's Illumineer, Brian Chemel, co-founded Digital Lumens with an eye toward the future of SSL being based upon advances in networks and controls that would enable smart buildings. Digital Lumens' LightRules software-based lighting management system and its accompanying lineup of digital lighting products is an example of the power of intelligent illumination that enables automated systems across commercial and industrial buildings (http://bit.ly/1pJka0P). Digital Lumens arrived on the scene several years ago as a pure-play startup focused on networked lighting and Chemel has led that company to success in what is now considered a mainstream market, but was a nascent market when the company hit the scene boldly promising 90% energy savings.

The Digital Lumens product and software lineup includes LED high-bay and linear fixtures; both mobile and standard software control platforms, as well as control for emergency lighting; sensor modules; and professional services for lighting projects. Energy-efficient light fixtures illuminate spaces, integrated sensors collect data, and analytics software scrutinizes that operational information, so LightRules and the intelligent lighting portfolio allow facilities to achieve efficient operations and space usage across an entire building. Indeed, Chemel has led the company to enable benefits far beyond reducing lighting power consumption. Chemel's vision of integrating controls based on wireless network connectivity has led the company to install its intelligent LED lighting system for 1000 customers across the globe.

Indoor Ambient, Track, and Accent SSL Luminaire Design

This indoor luminaire category featured outstanding design characteristics as well as true aesthetic qualities in all of the finalists and even other entries. Acuity Brands Lighting took home the award for the Gotham Incito 2" Family, which includes 2-in.-aperture fixtures for use as downlights, wallwashers, and other lighting applications. The narrow aperture enables precise beam control that is critical to many accent lighting applications, and the relatively small products can fit in tight areas. There are adjustable fixtures, a model with adjustable lenses, and cylinder models. Although the external appearance of the luminaires may seem simple, the robust internal design and quality components deliver excellent illumination in layered-lighting applications. One example might be spotlighting works of art. Lighting is customized to each application with field-interchangeable optics that tailor light levels and beam angles to precision. Some models are capable of delivering up to 1500 lm.

Connected Residential SSL Lamp Design

The connected residential lamp category was notable in that all of the finalists have products that take advantage of Bluetooth connectivity. That wireless interconnect is becoming a bigger player with emerging mesh extensions, and can enable the addition of other features to a lamp. Indeed, connected indoor LED lamps have progressed beyond simply employing apps as a smart remote to turn lights off and on. Sengled was awarded the connected lamp honor for its Pulse family of lamps, dual-capability smart LED lamps with a powerful hook — the combination of a BR30 downlight with a JBL-based audio system. The original Pulse product enables streaming audio over Bluetooth and playback that is superior to many of the dedicated Bluetooth speakers on the market (http://bit.ly/20YgyHj). The newer Pulse Flex works both indoors and out due its wet-location rating and relies on Wi-Fi technology. The Wi-Fi smart speaker-lamp supports AirPlay and DLNA networking standards, and once connected to the home network also can stream directly from popular Internet and app-based audio streaming services. The Sengled Pulse app enables home users to control the lighting and music by zones with user-specified lighting schemes and audio playback settings for an integrated home audio and lighting experience.

Sengled Pulse Flex Lamp.

LED Drivers

At their foundation, LED drivers provide power to LEDs and the systems in which they are integrated. But the driver is equally

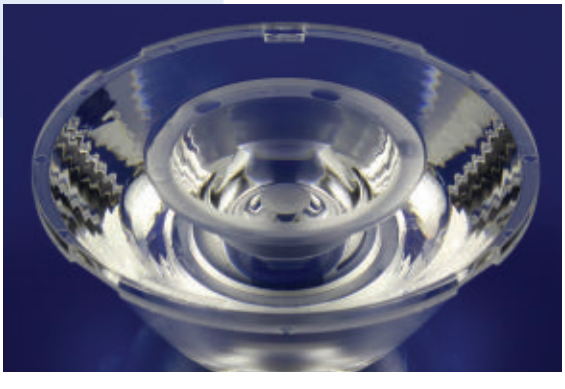
important to the LEDs in terms of quality, flicker-free light output and provides the natural spot for integration of advanced feature sets. Indeed, now drivers are imbued with much more dynamic functions, as in the case of the wireless driver developed by Daintree Networks with LG Innotek (http://bit.ly/1cxPv1d), which won this year's LED Drivers Sapphire Award. The integrated driver is engineered to eliminate the need for a separate wireless controller in addition to delivering the constant current required for LEDs. An out-of-the-box wireless control product enables fixture manufacturers to achieve a faster time to market with new LED troffers and retrofit kits, while focusing on simplifying fixture design and eliminating extra wiring. Using the ZigBee open-standard protocol means that any ZigBee-compatible network and software platform will allow machine-to-machine communications based around the lighting system in commercial buildings. Daintree supports the wireless LED driver with the company's ControlScope networked lighting control and building automation platform. The company says the duo can help lighting manufacturers reduce bill-of-materials (BOM) costs by up to 85% and post-installation energy consumption by up to 90%.

Daintree Networks/LG Innotek Wireless LED Driver.

SSL Enabling Technologies

The supplementary components in LED systems can sometimes be overlooked when it comes to industry recognition. But engineers and product developers know that the optics, lenses, materials, and thermal management components can truly make an SSL product that shines above the rest, which is why Fraen Corporation received the Sapphire Award for its Fraen Nested Lens. The low-profile, multi-TIR (total internal reflection) nested lens is engineered to produce narrow-beam light when employed with chip-on-board (COB) and domeless packaged LEDs (http://bit.ly/1CDtat3). The nested lens format reduces the height of the optics due to its dual TIR elements that create multiple surfaces with air gaps in between to lessen the etendue effect. The reduced height of the TIR lens helps to diminish the space needed in a luminaire to accommodate COB LEDs and provide more room for thermal management and power devices. The lens is designed to improve control of the center beam and reduce off-axis glare. Fraen touts its multi-TIR product for use in PAR20 and 38 LED lamps; downlights, tasklights, and tracklights; and in applications such as hospitality, retail, commercial, and general lighting.

Texas Instruments TPS92661-Q1 LED Matrix Manager.



Fraen Corporation's Nested Lens.

ICs and Electronic Components for SSL

Power and task management of LED systems that are implemented in LED drivers are generally features attributable to integrated circuits (ICs) and other electronic components that provide support for diverse applications. Examples include niche product developments such as steerable-beam automotive headlamps (http://bit.ly/1ntlzsD). Texas Instruments' (TI) TPS92661-Q1 LED Matrix Manager, recognized with the Sapphire Award in this electronics category, is such a device. The scalable controller IC meets AEC-Q100 Grade 1 specification for automotive applications, and can even be designed into transportation and outdoor/

commercial lighting and automation systems beyond the intelligent auto headlamp. Twelve individually-controlled MOSFET switches steer current through or around connected LEDs, which enables the controller to drill down to light adjustment at the pixel level — appropriate for the aforementioned steerable-beam designs, as well as various beam patterns and intensity levels. The TPS92661-Q1 IC can control up to 96 LEDs from one serial port and provides separate pulsewidth-modulation (PWM) control for each LED. What's truly innovative about these features is that the IC can report headlamp failure or damage alerts to the driver via the master controller using open/short fault diagnostics. TI claims a 73% reduction in board space, with the compact device mounting directly to a metal-core printed-circuit board (MCPCB) where the LED array is mounted.

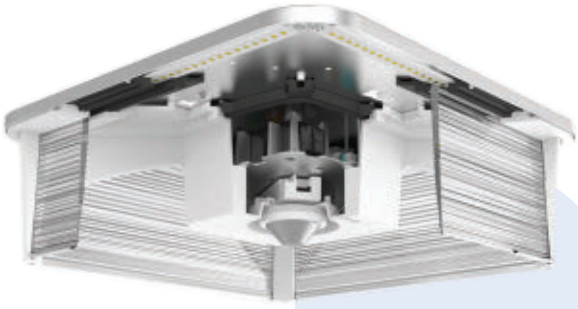
Dual-Lite NEMA 4X Dynamo Emergency Light.

Industrial SSL Luminaire Design

Industrial luminaires operate under some of the harshest conditions and must meet stringent requirements in order to maintain their integrity and performance. The Sapphire winner for the industrial category, Dual-Lite's NEMA 4X Dynamo Emergency Light, is an emergency egress LED luminaire designed with dual sealed, heat-dissipating lamp heads fabricated from aluminum to withstand use in harsh environmental conditions. It can also be equipped with an impact-resistant shield for washdown scenarios such as in food and beverage processing areas. The Dynamo meets upcoming changes to California Title 24 energy consumption requirements and includes an industry-first lifetime LED warranty. The environmentally-friendly, long-life battery with a microcontroller-based charger enables the luminaire to deliver a minimum of 90 minutes of illumination after primary power loss. High output means the LED emergency light can be broadly spaced on lamp posts, trusses, or walls.

Modular LED Light Engines

When the intent behind using a modular light engine is to simplify system design with fewer components and reduce development costs, a product needs more special features to make it stand out among the rest. Sapphire Award winner Xicato developed its 90-lm/W XIM (Xicato Intelligent Module; http://bit.ly/1ljJ7wB) with an integrated driver that achieves smooth dimming down to 0.1% with DALI control and 1% with 0–10V dimming technology while meeting the IEEE 1789-2015 standard on light flicker. In addition to dimming, Xicato has focused its efforts on color rendering and consistency features, using its own Corrected Cold Phosphor (a remote-phosphor technology) to maintain color consistency of 1×2 MacAdam ellipses; the LED modules are reported to stay within 3 MacAdam ellipses after 50,000 hours of operation. (Read more about remote phosphor technology in our feature from October 2013 at http://bit.ly/MS1tGR). The availability of a range of CRIs and lumen outputs and 19-mm and 9-mm beam packages allows fixture designers more flexibility in size and form factor in their SSL end products. What's more, the XIM products are compatible with connected lighting capabilities including programmable flux settings and wireless communication — for example, Bluetooth Smart, the latest Bluetooth wireless platform that will be available this year (see our feature on page 35 for more information on Bluetooth Smart and its use in networked lighting systems).



Cree's IG Series LED Parking Garage Luminaire.

Outdoor SSL Luminaire Design

Outdoor lighting poses particular challenges when designing for both form and function. But the devil is in the technical details, such as components that minimize glare and enable proper visibility for drivers and pedestrians. This year, Cree's IG Series LED Parking Garage Luminaire achieves Sapphire honors for its edge-lit optical waveguide design that achieves the low-glare goal. Cree first announced its WaveMax technology for edge lighting and its use in the IG LED luminaire last April (http://bit.ly/1F8dJcg). Leveraging the TIR principle in the optical waveguide platform, the microscopic DiamondFacet optical elements release and control light with smooth distribution and provide uplighting that prevents a cave-like effect. To satisfy safety and security requirements in the application, the IG Series luminaire meets IESNA RP20-14 basic and IESNA Security Zone G-1-03 requirements. The impact-resistant polycarbonate and acrylic body weighs less than 10 lb, and the luminaire is

Xicato Intelligent Module (XIM).

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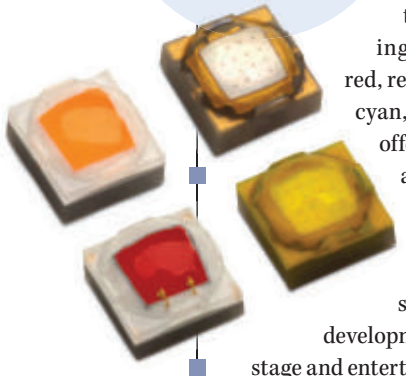
Packaged LEDs and OLED Panels

Packaged LEDs are indeed a bright spot in the LED market. A rainbow of LEDs, such as the Sapphire-winning Lumileds Luxeon C Color Line, designed for maximum light extraction and the right color mixes can make any color lighting application possible (http://bit.ly/1YlkHaf). The 2×2-mm color and white packaged LEDs use a low-domed design for a minimally magnified light source with high luminance. Mixing traditional color LEDs to achieve various color combinations can prove challenging due to varied focal lengths as a result of different die and epitaxy architectures. Customers would typically resort to one type of optic to use with the varied-color LEDs, which resulted in rings of unmixed colors or halos (http://bit.ly/1KxS2Tu). But Lumileds addressed this problem by offering color LEDs with one consistent focal length, producing its current lineup with red, red-orange, PC amber, green, cyan, blue, royal blue, and white offerings. Additional colors will also be available this year. The low-profile design, Lumileds says, also improves the light extraction to emit a narrow beam with a consistent pattern to support product development for applications such as color stage and entertainment lighting, and even architectural lighting.



Lumileds Luxeon C Color Line of packaged LEDs.

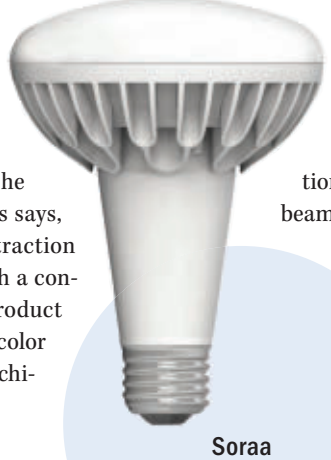
Specialty SSL Design

Specialized applications outside of general illumination may cover industrial or scientific tasks, medical or health-related functions, and more. UV LEDs have been used in sanitizing and disinfection applications, but the Sapphire Award winner — the Indigo-Clean Continuous Disinfection 405-nm visible-light system by Kenall Manufacturing — kills microorganisms to disinfect air and surfaces in clinical environments, helping to reduce cross-contamination from various facilities, rooms, and procedural areas. The disinfection technology has exhibited 86% disinfection beyond current cleaning protocols in studies. Three configurations cover various uses and cost levels: Blended White for overhead light and continuous disinfection; Indigo-Only for disinfection only; and Switchable White/Indigo for changing from overhead ambient light to 405-nm disinfecting light as needed. The LED luminaires can eliminate the need to shut down clinical spaces for disinfection, and work on both hard surfaces and in the air safely and continuously to maintain usability of areas from waiting rooms to patient rooms to operating theaters and beyond.

Kenall Manufacturing Indigo-Clean Continuous Disinfection light system.

SSL Lamp Design

Within the past few years, the SSL industry has determined that in order to please customers and see a greater uptake, an LED lamp needs to be more than a replacement for the incandescent bulb. SSL lamps like the Sapphire Award-winning Soraa VIVID BR30 LED Lamp are now designed to provide illumination comparable in quality and color temperature to that of conventional halogen lamps, delivering precise beams of light that can enhance retail merchandising, for example, or properly highlight the exquisite colors and details of museum collections. Available in 2700K and 3000K CCT, the lamps are compatible with various dimmers and can be used indoors and out. The omnidirectional output is rendered with both CRI and R9 greater than 90. The 730-lm BR30 lamp uses 13W and is suitable for replacing 65W halogen lamps with its efficacy reaching above 60 lm/W. And Violet-Emission 3-Phosphor (VP3) LED technology for brilliant white rendering and accurate warm tones helps end users see the world in a whole new light.



Soraa VIVID BR30 LED Lamp.

SSL Network and Control Technologies

Software applications and digital controls can do more now than manage light levels. Kenall Manufacturing's Sapphire-winning TekLink Parking Controls provide integrated lighting and controls when combined with TekDek

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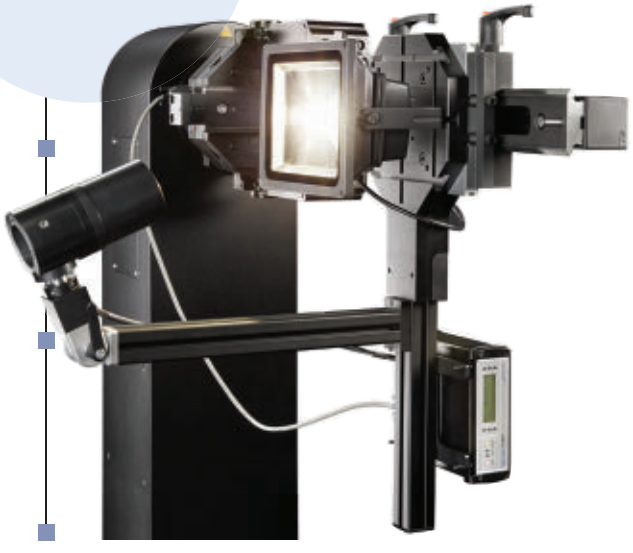
Kenall Manufacturing TekLink Parking Controls.

and TopDek LED luminaires for parking garage and lot lighting. The system is available in multiple configurations including non-networked, wired, and cloud-based controls. Control options for various application requirements and budgets range from simple sensor-based occupancy detection to daylight sensing for automated modification of light output. Daylight harvesting is even possible with specific fixture and controls combinations. More robust features such as reporting, scheduling and programming of lighting schemes, and a secure cloud-based, 3-D parking garage GUI offer facilities managers a user-friendly way to optimize energy efficiency and determine appropriate lighting conditions based on data.

Tools and Tests in SSL Design

No SSL product can be truly ready for market without appropriate testing and quality assurance, and tools and services can help SSL manufacturers speed time to market. Light sources are measured using specialized equipment for photometric and colorimetric parameters that the designer is expected to achieve. Instrument Systems offers the Burning Position Correction for Gonio, the Sapphire winner in the tools and tests category, as an option for its LGS 1000 goniophotometer system. The "Burning Position Correction" option allows the turning luminaire goniometer to be fully compliant to the international SSL measurement standard CIE S025 (released in 2015) and the European equivalent EN 13032-4. The add-on can correct measurements that do not fall within the intended burning position parameters of the device under test (DUT). The innovation lies in the fact that the company designed the method for adding on to existing turning luminaire goniometers, helping luminaire product developers to increase the capability of their testing equipment without the extra cost of new equipment while also improving the accuracy of SSL product metrics.

Instrument Systems Burning Position Correction for Gonio.



Indoor Troffer, Linear, and Recessed SSL Luminaire Design

Indoor ceiling area and linear lighting is especially abundant in commercial spaces, retail, and educational and municipal buildings. The volume of installed lighting presents an enormous opportunity for indoor SSL manufacturers (http://bit.ly/1eQhQk9). As previously mentioned, Cree's edge-lit Wavemax technology produces uniform illumination with high efficacy, but it also streamlines the design of the winning LN4 Suspended Ambient LED Luminaire, available with up to 3400 lm and choice of 3500K and 4000K CCT. The luminaire delivers up to 110-lm/W output in efficacy and achieves CRI greater than 90 using Cree's TrueWhite technology, which LED product development leader Paul Scheidt explained in an interview at LightFair International last year (http://bit.ly/1EXZ9B2). Modularity of the LN Series is supported with a standard 48-in. LED light engine and optional integrated SmartCast lighting controls. The luminaire is equipped with standard 0–10V dimming.

Cree LN4 Suspended Ambient LED Luminaire.

Tunable SSL Technology

Finally, we make our way to tunable SSL technology as it stands in its own spotlight, with the ability to manipulate light output for various experiences. Winner Finelite's CEO Terry Clark addressed the complexities and research in tunable lighting as it may be used in a human-centric lighting (HCL) capacity, such as enhancing productivity, improving healing in medical settings, or creating a welcoming hospitality or retail environment, in a 2014 interview (http://bit.ly/1q7GM4G) by putting the company's development of tunable SSL into context.

Finelite FineTune White Color Tuning System.

The FineTune White Color Tuning System by Finelite gives users the ability to tune light from warm to cool CCTs as well as changing the intensity with dimming from 100% down to 0.01%. The dynamic tunable SSL system is compatible with many of the company's LED luminaires; it includes the necessary cables for plug-and-play installation. The system supports DMX, DALI, and Power over Ethernet architectures, and may be managed via wall-mounted controls and a free smartphone app. Finelite white color-tuning luminaires connected to the Finetune system are reported to attain 90% lumen maintenance at 100,000 hours.

The Finelite system is yet another example of the SSL industry moving to bridge the disconnect between more-capable, multi-channel LED-based products and easy-to-use control platforms. As we look forward to our third-year Sapphire program that will launch in a few months, we expect to see even more intelligence embedded in products linked to intuitive control platforms.

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Driverless AC-LED light engines deliver improved flicker performance

Driverless AC-LED light engines are a convenient, economical replacement for the traditional driver plus LED configuration, and **PETER SHACKLE** explores a new topology that delivers significantly better flicker performance.

The solid-state lighting (SSL) community has continued to explore the possibilities of so-called AC-LED technology because such a driver circuit for an LED light engine is much simpler than the standard AC/DC driver. However, up until the present time, many specifiers have been reluctant to use AC or driverless light engines because the light was characterized by a flicker index around 0.32. In this article, we will present a new approach to AC-LED light engines that use higher frequencies to deliver a flicker index of 0.15 simultaneously combined with a power factor of 0.9.

Flicker index is a concept that has been around since 1952, and its companion concept percentage flicker was first defined in the year 2000. The IES (Illuminating Engineering Society) handbook published the graph shown in Fig. 1, which defines both of these concepts. Flicker first came to public attention in the 1970s when a correlation was found between the flicker present in magnetic ballasted fluorescent lights and the headaches and eye strain suffered by a small percentage of mostly office workers who worked in the presence of these lights. Following this recognition, magnetic ballasted fluorescent lights were gradually replaced by high-frequency electronic ballasted fluorescent lights throughout the 1990s and the complaints of headache and eye strain ceased.

PETER W. SHACKLE *(pshackle@photalume.com) is an inventor and patent consultant who works on driverless LED light engines under the business name Photalume.*

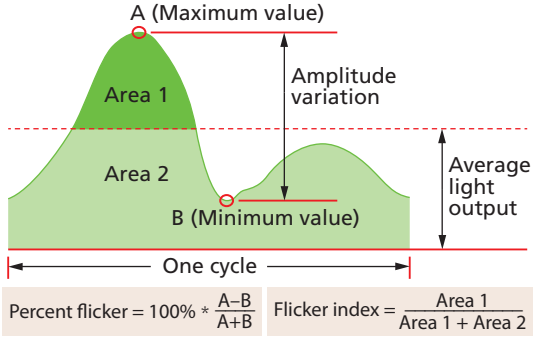


FIG. 1. The IES defined flicker index and percentage flicker metrics based on this graph.

Flicker challenge

Fast-forward now to 2015, and LED lamps and luminaires are finding widespread use. There have been flicker issues across a broad range of SSL products for general illumination, including poorly designed products that use AC/DC drivers. Still, the AC-LED technology is our focus here because flicker is one of a few issues that are gating more widespread adoption of the technology, which otherwise may prove more cost effective and reliable compared to AC/DC designs.

Fig. 2 shows the light output profile of a conventional 2015 driverless AC light engine. The flicker index is 0.309 and the percent flicker is 100%, which simply reflects the fact that at certain points during the line power cycle the instantaneous light output goes through zero. For comparison, the light output profile of a typical halogen replacement lamp using LEDs has a flicker index of 0.105.

Michael Poplawski and Naomi Miller of the US Department of Energy (DOE) Pacific Northwest National Laboratory (PNNL) documented the light output profiles for a number of light sources in a 2011 presentation at an IES conference (http://bit.ly/1XjeXcX). These waveforms give a feel for what typical instantaneous light waveforms look like, and their associated flicker index numbers.

Acknowledging frequency

Both of the standard measures of flicker index and percentage flicker have a weakness in that they do not take into account the frequency sensitivity of the human eye. In 1988, Sam Berman and others had some heroic volunteers have electrodes attached to their eyes in order to pick up the electrical impulses resulting from high-frequency light pulses as they went to the brain through the optic nerve (http://1.usa.gov/1TT119F). The results showed that the sensitivity decreases rapidly with increasing frequency, being down by roughly 1000× by a frequency of 200 Hz

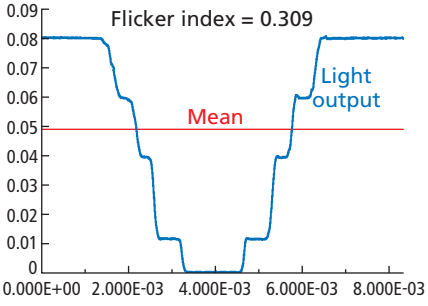


FIG. 2. Typical AC-LED light engines have had a relatively high flicker index.

and not being recorded for higher frequencies. For this reason, suggestions have sometimes been made that to represent what the eye perceives, all frequencies above 200 Hz should be filtered out.

In 2015, the Lighting Research Center (LRC) at Rensselaer Polytechnic Institute described a flicker metric that reflects the sensitivity of the human eye, based on the frequencies that 50% of subjects could perceive (http://bit.ly/1WegKOp). However, prior research by E.M. Jaen in 2011 had shown that human visual performance is degraded by the presence of high-frequency flicker even when the subjects involved were not capable of perceiving the flicker directly (http://bit.ly/1o3Tk4E).

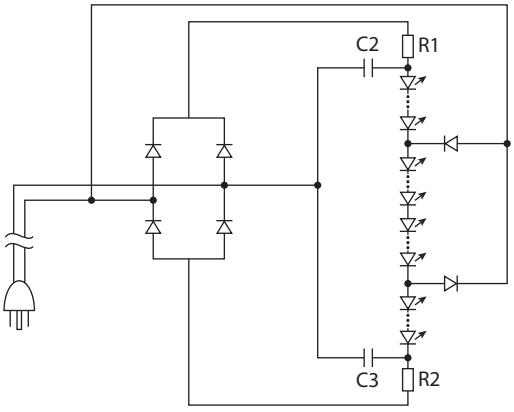
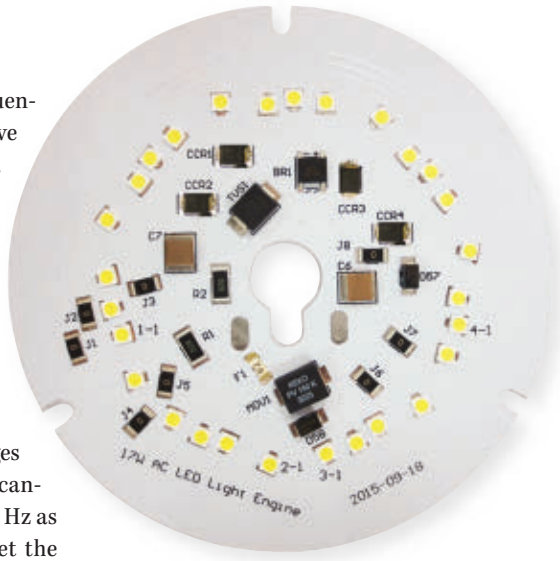


FIG. 3. The circuit represents a fourth-generation AC-LED light engine.

A consistent picture emerges here. Half of human beings cannot perceive flicker above 60 Hz as documented by the LRC, yet the work of Berman shows that frequencies up to 200 Hz are indeed being transmitted to the brain, and Jaen confirms that visual performance is degraded even when subjects cannot perceive the flicker. The 200-Hz limit corresponds to a frequency having a time period of 5 msec (milliseconds), which makes the point that a gap in a waveform on the order of, say, 2 msec or less will be imperceptible because the human eye cannot detect and signal the existence of such



Source: Segue Electronics.

FIG. 4. The circuit from Fig. 3 was implemented in this modular product by Segue Electronics.

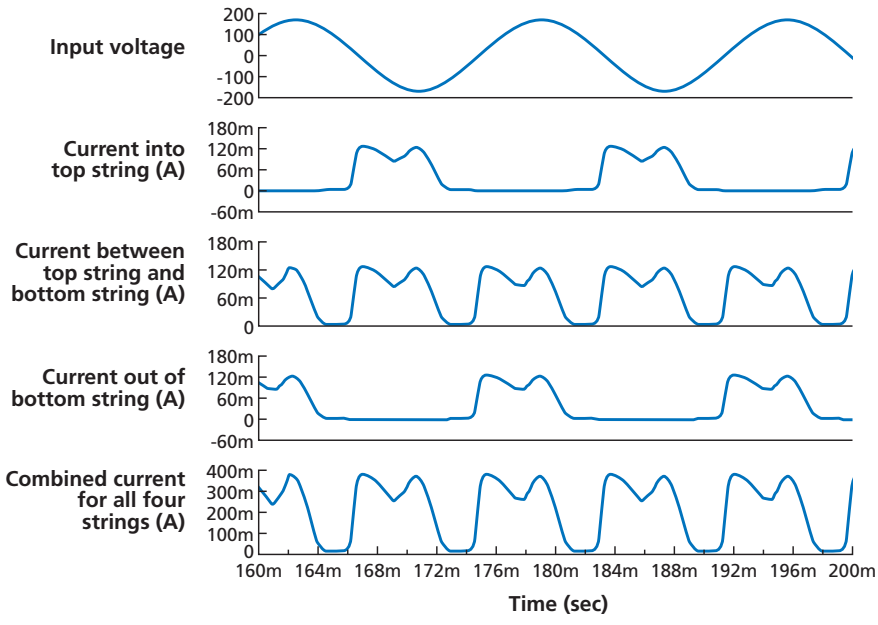


FIG. 5. A graph of current through the LED strings relative to line voltage shows short gaps in light output.

fast events. This knowledge can serve as the basis of a circuit that achieves simultaneously low flicker index and high power factor.

New driverless topology

Last year, we had described what we considered to be a fourth generation of driverless AC-LED light engines (http://bit.ly/23XwewS). That circuit is shown in Fig. 3. The circuit achieves a power factor greater than 0.7 — suitable for Energy Star consumer applications — and a flicker index of 0.28, which was at the time better than any AC-LED light engine available. Fig. 4 shows an example of a light engine made using this circuit. The resistors shown in the theoretical circuit of Fig. 3 have been replaced by current controlled resistors (CCRs) to get better voltage regulation of the light, and conventional voltage surge-protection components have been added.

This simple-looking circuit contains four identical strings of LEDs, all connected together in series. In the design simulation its electrical efficiency is 87%, although this drops slightly in real life when surge protection circuitry is added. One aspect of these light engines is that the innermost two LED strings produce light every half cycle, whereas the two outer LED strings produce light on every other half cycle.

The light output from the two outer strings comes from the top string on one half cycle and from the bottom string on the next half cycle. In order to get the light output to be blended uniformly, each LED from the topmost string is placed as close as possible to a corresponding LED from the bottommost string. This arrangement can be seen in the actual circuit shown in Fig. 4. In order to minimize the number of components, integrated LED pairs are used for each LED component instead of using discrete LEDs. Fig. 5 shows the computed current through each of the four strings plotted over time, compared to the power line voltage. It can be seen that the combined current is relatively flat, except for a 2-msec gap every half cycle.

What is intriguing about Fig. 5 is that the 2-msec gap does not happen at the line voltage zero crossing but instead just past the peak of the line voltage waveform. The 0.73 power factor comes about because there is little current drain just after the peak of the power line voltage. The flicker index is as high as 0.28 because there is no light output in this same time period just after each peak of the power line voltage. If we contrive to

draw some current from the power line and pass it through LEDs during this time interval, then the power factor can be improved and the flicker index can be decreased. This concept gives birth to the commercial and industrial circuit shown in Fig. 6 — the Photalume light engine.

High PF and low flicker

The circuit in Fig. 6 contains the consumer circuit previously described but now with the addition of a fifth string of LEDs, which comes on during the gap in the light output of the original circuit. A control circuit turns it on only when the line voltage is below a certain level and declining. The instantaneous value of the measured light output over time is shown in Fig. 7. There are two dips in light output per half cycle, one approximately for 1 msec and one with duration of less than a msec. These brief dips are imperceptible to the human eye and hence the perceived light quality is better than would be expected from the 0.152 flicker index.

A common question is how does this performance relate to the requirements of IEEE 1789-2015, a standard that makes recommendations about light flicker content (http://bit.ly/1hNX4TT)? That standard is limited to sinusoidal light output fluctuations, which this waveform is very clearly not; hence IEEE 1789 does not apply to this waveform. Since the fifth string only operates for a small fraction of each cycle, it is acceptable to simply limit the LED current with resistors, which has only a minor impact on the overall efficiency.

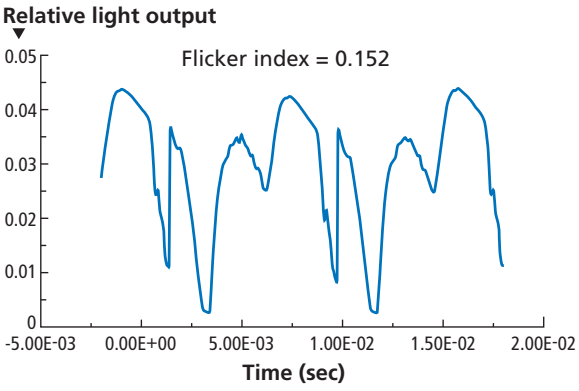


FIG. 7. The graph of light output from the circuit in Fig. 6 shows a much lower flicker index.

Fig. 8 shows an example of a light engine made using the commercial/industrial circuit of Fig. 6. This circuit has surge protection circuitry consisting of a metal oxide varistor (MOV), voltage dropping resistors, and a transient voltage suppressor (TVS), enabling it to withstand conventional voltage surge tests. The power lost in the voltage dropping resistors lowers the efficiency to 83%. The table shows a summary of the performance data. When running on a bench in open air, a 10W version of the light engine runs at a temperature of 60°C, reflecting its level of efficiency.

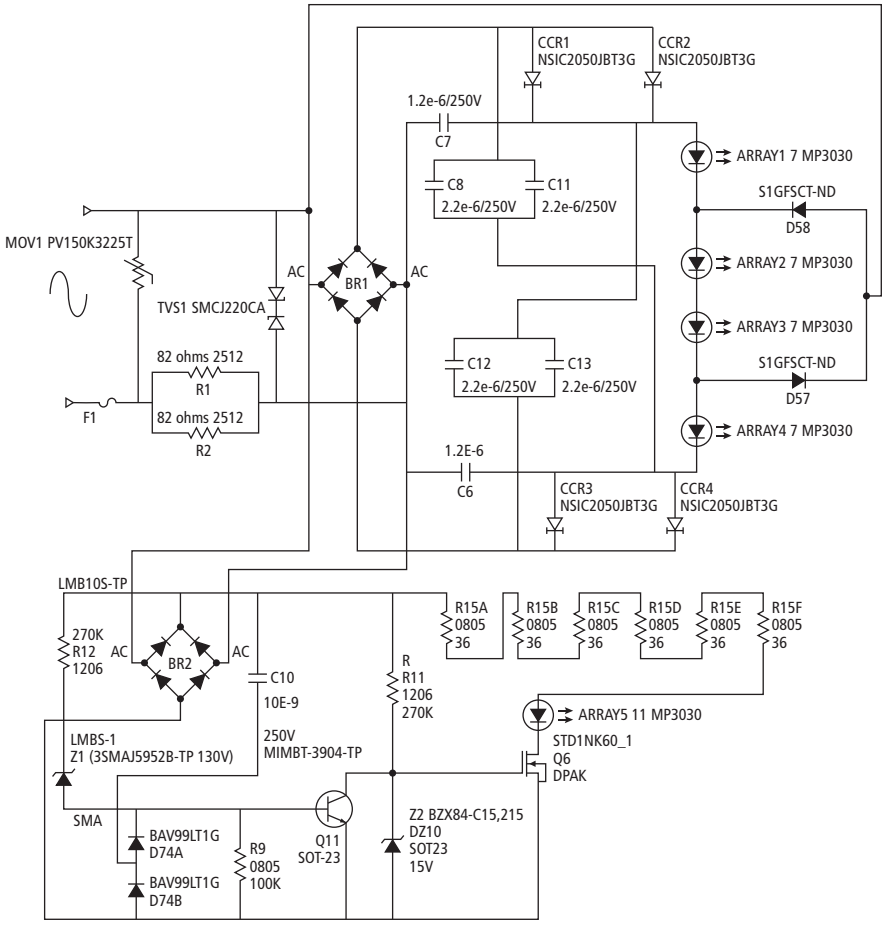


FIG. 6. A newer AC-LED topology adds a fifth string of LEDs to enable more uniform light output.

Light engine performance

An interesting property of the light output waveform of this light engine is that the modulation is at frequencies that are too high for the human eye to perceive. As previously described, a good approximation to what the human eye can perceive can be achieved by simply putting the light output through a 200-Hz low-pass filter. In this case, a 4th order Butterworth filter was used, and the percentage flicker that was nearly 100% was reduced to only 22% when the light output waveform was filtered in the way that corresponds to human eye capability.

The light output of the light engine increases with the input line voltage. A 10% increase in line voltage gives 6.4% increase in light output.

The dimming performance of the light engine is of particular interest. Since the circuit contains capacitors, albeit small ones, a so-called capacitive dimmer (otherwise known as a trailing edge dimmer, an electronic low-voltage [ELV] dimmer, or reverse phase control dimmer) must be used. In this way the product can be dimmed down

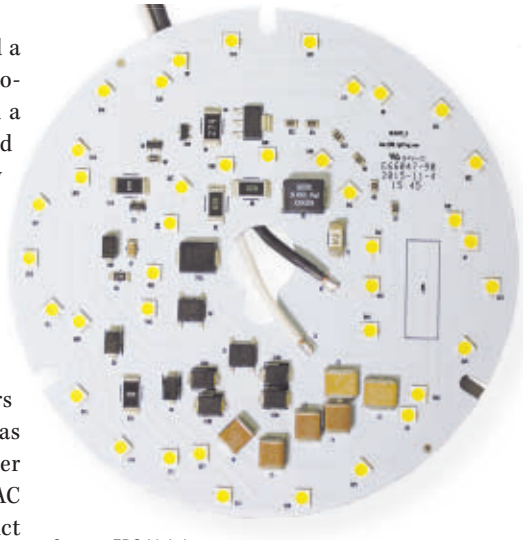
to 2.8% without any instability. The flicker index increases as the dimming progresses, similar to what is observed with any AC-LED driverless light engine.

In the previously mentioned 2011 work conducted by Poplawski and Miller at PNNL, a number of AC-LED light engines were tested and it was reported that all had a flicker index of 0.42. In 2015, the best AC-LED light engines available had a flicker index of 0.32. Now, in 2016, the Photalume light engine is performing with a flicker index of 0.15. This is being achieved by storing up minute amounts of energy on chip capacitors and releasing it at just the right moment. The result of this is a driverless light engine that is flat and efficient, and combines a power factor of 0.90 with a flicker index of 0.15.

For basic lighting applications, it is a good prediction that separate LED drivers are becoming increasingly unnecessary as the old-fashioned concept of LED driver plus LEDs is replaced by the driverless AC light engine. In particular, one may predict a future in which luminaires using these thin, efficient light engines might simply be placed flat on ceilings with only small wire holes, a useful convenience and cost reduction. Large-scale versions of these circuits have been designed that are suitable for high-bay lights, street lights, and other powerful applications.

Performance data for the Photalume light engine.

Power factor	0.90
Flicker index	0.152
Total harmonic distortion	35%
Electrical efficiency	83%
Dimming range	Down to 2.8% with ELV dimmer
Efficacy	120 lm/W (depends on LEDs chosen)
Input voltage range	108–132V, 60Hz
**Versions are being designed for 230V, 50 Hz*	



Source: ERG Lighting.

FIG. 8. The circuit from Fig. 6 is captured in this modular LED light engine manufactured by ERG Lighting.

The circuits described in this article are patent pending. Licenses may be obtained from Photalume.

Custom vs. commodity: Factors for thought about LED light engines

Depending on fixture design, MADE freelance writer **ED SULLIVAN** asserts that off-the-shelf light engines for SSL product developments may be inefficient and create a production bottleneck.

As LED lighting products continue to proliferate, some LED lighting manufacturers compromise the performance of their fixtures due to industry-wide efforts aimed at the development of standard specifications for LED light engines (LEs). Ramifications of an off-the-shelf modular LE selection could include unsatisfactory light output, poor efficacy (lm/w), increased assembly time and costs, as well as delivery delays and other problems that can be avoided. Such commodity LEs can be perceived to be a standardized product that provides ready availability and cost savings, but product developers should scrutinize the LE specification decision to ensure optimum end products.

The fact that many LEs are produced in high volume doesn't necessarily make them the best value. Nor should they necessarily be the standard approach to an LE for lighting companies. In many instances, lighting manufacturers need design latitude in terms of sizes, shapes, mounting hole locations, as well as light output and color temperature that comprise their product's value proposition.

Flexibility in fixture dimensions can be problematic when using commodity LEs. If a lighting manufacturer has a market for LED fixtures that are longer or wider than usual, they may have to improvise multiple LE modules in order to power the fixture, and that usually means more costly, time-consuming assembly. The finished fixture's efficacy or light quality may suffer including uniformity issues that may dissatisfy end users.

Conversely, custom LEs are expressly designed and manufactured to fit the lighting output and size requirements of specific fixtures. Such a result is accomplished by the LE design engineers interacting directly with fixture manufacturers on each product: understanding their goals, what the fixture looks like, and light output targets. These engineers also determine how many LEDs are optimum, or if a bigger panel is required.

Lighting manufacturers may be better off evaluating the use of customized LEs for their fixtures. Light engine manufacturers, like MADE (Manufacturing And Design Electronics), will take the conceptual product information, lay out an LE board, build it, and then deliver samples to the lighting company for them to test in their fixture. All of this is done efficiently — often satisfying the customer's true requirements with the first samples.

When lighting companies simply adopt an available commodity LE, in many instances that equates to ignoring the lighting objectives and design targets for the conceived fixture. Lighting companies should have efficacy targets and light output targets for the fixtures they are creating. Once these are determined, the LE manufacturer can make some pretty good assumptions on the efficiency of the light output and the light transfer from the light source to the fixture level. The experience of the LE specialists enables them to develop the right solution so fixture makers hit their design targets and get the required certifications more easily.

Settling for a commodity module can often result in discovery that a project did not quite hit the identified targets. Such an occurrence might result in adaptations such as trying an increased drive current, which then may not achieve the efficacy goal.

Cost is usually a dominant consideration when a light fixture manufacturer selects a standard LE. But module costs can be misleading. Many manufacturers assume that they couldn't possibly buy a custom board for a competitive price. Yet it is entirely possible for a custom light engine company to produce a board for a highly competitive price, or perhaps for even less.

Still, the bigger issue may be system design and manufacturing costs. One of the major advantages of a custom LE is that it is easier to integrate into the light fixture, requiring fewer connections during assembly and resulting in time and labor savings. Moreover, there are other cost options that the custom LE manufacturer can recommend, such as matching the best LEDs to an application. The right choices can reduce power consumption and improve performance even if more-expensive or greater numbers of LEDs are used.

LE availability is another significant consideration. Lighting manufacturers may run into supply problems when a commodity LE manufacturer can't meet delivery requirements because a very large customer has just taken the entire inventory. Smaller custom LE makers are usually able to minimize delivery problems because they design and plan with their customers ahead of time, which results in consistent, dependable deliveries.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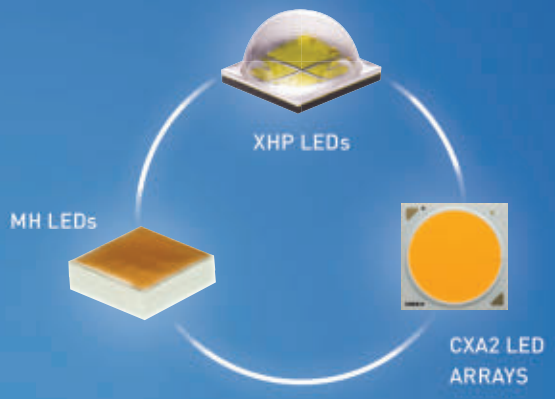

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